PLATE 1.

a

b

VIEWS SHOWING ENCROACHMENT OF VEGETATION ON WATER AREA OF LAKES.

(a) Lower end of Mabie, one of the Barbee lakes, Kosciusko County.
(b) Corner of West Cedar Lake, Whitley County.

(See Page 38.)

INDIANA.

DEPARTMENT

OF

Geology and Natural Resources.

TWENTY-FIFTH ANNUAL REPORT.

W. S. BLATCHLEY,

State Geologist.

1900

INDIANAPOLIS:
WM. B. BURFORD, CONTRACTOR FOR STATE PRINTING AND BINDING.
1901.

THE STATE OF INDIANA,
EXECUTIVE DEPARTMENT,
INDIANAPOLIS, February 1, 1901.

Received by the Governor, examined and referred to the Auditor of State for verification of the financial statement.

OFFICE OF AUDITOR OF STATE,
INDIANAPOLIS, February 1, 1901.

The within report, so far as the same relates to moneys drawn from the State Treasury, has been examined and found correct.

W. H. HART,
Auditor of State.

FEBRUARY 1, 1901.

Returned by the Auditor of State, with above certificate, and transmitted to Secretary of State for publication, upon the order of the Board of Commissioners of Public Printing and Binding.

CHAS. E. WILSON,
Private Secretary.

Filed in the office of the Secretary of State of the State of Indiana, February 1, 1901.

UNION B. HUNT,
Secretary of State.

Received the within report and delivered to the printer this 1st day of February, 1901.

THOS. J. CARTER,
Clerk Printing Bureau.

State of Indiana, Department of Geology and Natural Resources.

INDIANAPOLIS, IND., February 1, 1901.

HON. W. T. DURBIN, *Governor of Indiana:*

DEAR SIR—I have the honor to submit to you herewith the manuscript of the Twenty-Fifth Annual Report of the Department of Geology. It comprises, in the main, papers of economic importance relating to the resources of the State suitable for the manufacture of Portland and Hydraulic Cements, together with the reports of the chiefs of the different divisions of the Department for the calendar year 1900.

Yours very truly,

W. S. BLATCHLEY,

State Geologist.

ASSISTANTS.

GEO. H. ASHLEY*..	Chief Assistant.
E. M. KINDLE, Franklin, Ind.	Paleontologist.
C. E. SIEBENTHAL, Bloomington, Ind.	Assistant.
J. T. SCOVELL, Terre Haute, Ind.	Assistant.
W. A. NOYES, Terre Haute, Ind	Chemist.
W. C. ZARING, Indianapolis, Ind.	Supervisor of Oil Inspection.
J. C. LEACH, Kokomo, Ind.	Supervisor of Natural Gas.
JAMES EPPERSON, Linton, Ind.	Inspector of Mines.
CHAS. LONG, Coal Bluff, Ind.	Assistant Inspector of Mines.
ISADORE KESSLER, Indianapolis, Ind.	Stenographer.

* Resigned October 1st, 1900, to accept the Chair of Biology and Geology in Charleston University, Charleston, South Carolina.

TABLE OF CONTENTS.

DEPARTMENT OF GEOLOGY AND NATURAL RESOURCES.

INDIANAPOLIS, IND.

W. S. BLATCHLEY, State Geologist.

PLEASE ACKNOWLEDGE RECEIPT OF THIS VOLUME.

In return, Scientific Books, Fossils, etc., and Implements of the "Stone Age" are acceptable.

State Museum, Room 126, Third Floor, State House.
Open to the public from 8 A. M. to 5 P. M. except on Sundays and legal holidays.
Admission free.

Office of State Geologist, Room 89, Third Floor, State House.

INTRODUCTORY.

The present volume is the twenty-fifth in the series of annual reports issued by the Department of Geology of the State of Indiana, and the sixth issued under the auspices of the writer. In those portions of these six reports written by the State Geologist himself, he has ever tried to keep in mind the interests of the citizens of the State who pay the taxes to support the Department rather than the interests of professional geologists. In other words, he has attempted to prepare reports which the common people can, for the most part, readily understand. Believing that the advertising of the natural resources of the State was the primary object held in view by the founders of the Department, he has made economic geology the main feature of his work. At the same time he has noted with pleasure the growing interest among teachers and pupils in the plants and animals about them and has attempted to add to this interest by publishing papers by well-known investigators on the flora and fauna of the State. With the exception of scientific names, which can readily be passed over by all to whom they are unintelligible, as little technical matter as possible has been introduced in these papers bearing upon economic resources and natural history. Attempt has been made to verify, whenever it could be done, the statements given; to print the truth in the simplest language possible.

The present report includes the results of the principal field work carried on by the State Geologist and chief assistant in the autumn of 1899 and the season of 1900. This was the exploration of the lakes and marshes of northern Indiana in search of deposits of marl of suitable size and purity to justify the erection of factories for the manufacture of Portland cement. Under the present advanced methods of manufacture of this valuable commodity, capitalists do not care to invest the large sum necessary for the erection of a modern factory unless raw material enough is at hand to keep the factory running for 30 or more years. Careful estimates go to show that a factory with an output of 500 barrels of Portland cement each 24 hours will use in 30 years a body of marl 160 acres in area and 10 feet

thick.* Such a deposit is, in this report, termed a "workable deposit." The paper entitled "The Lakes of Northern Indiana and Their Associated Marl Deposits," gives full details concerning 32 such deposits of marl, which were found in the three northern tiers of counties of the State. The location of these workable deposits by counties, and the pages on which they are described in this report, are as follows:

STEUBEN COUNTY.

LAGRANGE COUNTY.

NOBLE COUNTY.

WHITLEY COUNTY.

ELKHART COUNTY.

KOSCIUSKO COUNTY.

*See page 52 of this volume.

Besides the above mentioned 32 deposits, 15 others were found, presumably of workable size, but with the larger portion of their area beneath 10 feet or more of water, and therefore not available under the present conditions of securing marl. There is little doubt but that appliances will soon be devised for raising marl from beneath any depth of water, and then these deposits can be classed with those already mentioned.

The details given relative to the area, depth, shape and aquatic flora and fauna of many of the lakes, together with the accompanying maps, will also, it is thought, be of interest and value to the large number of fishermen and sportsmen who annually visit their waters, as well as to the many cottagers who spend the summer months in their vicinity.

The paper on the "Silver Creek Hydraulic Limestone," by Mr. C. E. Siebenthal, contains full details regarding the location and stratigraphy of the stone so largely used in southern Indiana for the manufacture of natural rock cement, as well as an historic, descriptive and statistical account of the industry. It is accompanied by a map showing the exact distribution of the cement rock.

Mr. Siebenthal has also gathered for this report statistics relative to the oolitic stone industry in Indiana for the year 1900. These have been incorporated in a special paper which shows that there was quar-

ried during the year, 7,035,000 cubic feet, or approximately 23,000 car-loads of the oolitic stone, the value of which at the quarries was $1,699,649.

The annual reports of the State Supervisor of Natural Gas, Inspector of Mines, and Supervisor of Oil Inspection are included in the order mentioned. The report of the Supervisor of Natural Gas shows that the center of production, or that territory not invaded by pipe lines, in 1898 comprised 250 square miles in Grant, Madison, Blackford and Delaware counties. On the first day of January, 1901, it had been reduced to less than 50 square miles in the northwest corner of Delaware County. The main Indiana gas field, which comprised originally 2,850 square miles, is divided into three zones, viz.: (1) An outer zone, varying greatly in width, which has been abandoned by the pipe lines and supplies only a small amount of gas for local domestic use; (2) A middle zone, comprising at present probably 900 square miles, which is the main territory supplying the pipe lines and almost all of the factories; (3) The heart of the field or center of production above mentioned. In December, 1899, the average rock pressure of the middle and center zones only was 155 pounds. In December, 1900, the average in the same two zones was but 115 pounds. This drop of 40 pounds is more than twice as great a decrease as has occurred in any other year since natural gas was discovered in Indiana, and is an excellent index of the rapidity with which the supply is being exhausted.

The factories in the gas belt have many of them begun the use of other fuels and there is little doubt but that the great majority of them will remain where they are now located, gradually adopting that form of fuel best adapted to the production of their respective wares. To those that wish to remove to localities where cheap fuel exists in abundance, the coal-bearing counties of western Indiana offer, and will continue to offer, good sites, excellent railway facilities and an abundance of the finest grades of bituminous coal.

The report of the State Mine Inspector shows that 6,357,976 tons of coal were mined in Indiana in 1900. This was an increase of 492,853 tons over the output of 1899, which was the largest in the history of the State. This increase was due to the absence of the usual strikes on the part of the miners in the leading coal districts in the State, and to a steadily increasing demand for Indiana coal throughout the year. This demand was largely brought about by the gradual lessening of the supply of natural gas. There is no doubt but that the demand for Indiana coal will continue to increase as the supply of gas grows less, and the output will doubtless reach 10,000,000 tons per annum before the year 1910.

According to the report of Mr. Epperson, the relative rank of the fifteen coal producing counties for the year 1900, together with the output of each in tons and the amount of wages paid to miners, was as follows:*

TONS OF COAL PRODUCED AND WAGES PAID TO MINERS IN INDIANA IN 1900, BY COUNTIES.

	Number of Tons Produced.	*Wages Paid.*
Clay County	1,497,677	$1,111,832 44
Vigo County	809,884	723,977 37
Vermillion County	751,349	495,361 20
Sullivan County	748,678	558,620 98
Greene County	746,483	484,084 72
Parke County	679,024	611,119 45
Daviess County	254,030	201,482 65
Pike County	249,804	207,891 37
Warrick County	181,384	111,851 63
Vanderburgh County	172,562	191,293 53
Gibson County	59,420	43,663 50
Knox County	59,382	50,695 01
Fountain County	41,640	37,386 95
Perry County	23,480	11,259 05
Martin County	8,266	6,823 41
Total	6,283,063	$4,843,343 26
Total number of tons produced in small mines	74,913	39,680 92
Grand total	6,357,976	$4,883,024 18

The number of miners employed in mines operating 10 or more men was 8,858. In the smaller mines about 1,000 additional men were at work, so that nearly 10,000 coal miners are employed in the State.

Of the coal produced, 1,512,098 tons were block coal, and the remainder bituminous. Clay and Parke counties alone yielded block coal; Clay County producing 1,190,406 tons and Parke County the remainder, or 321,692 tons. The report of Mr. Epperson is very complete, containing several tables of statistics of different phases of the industry which have not been embraced in former reports of the State Mine Inspector.

A paper entitled "The Petroleum Industry in Indiana in 1900" follows the report of the State Mine Inspector. It gives in detail the

*The output given is only from mines working ten or more men.

developments and statistics of the industry in the Trenton rock oil fields during the year, as well as a full history of the productive areas recently opened up in the Corniferous rock at Loogootee, Martin County, and near Medarysville, Jasper County. An accurate map of the main Indiana oil field, brought up to January 1, 1901, also accompanies the paper.

The final paper in the volume is largely devoted to the fossil faunas of the Devonian rocks of the State, and will doubtless be especially interesting to paleontologists. In the last six reports issued by the Department, but one other, that for 1897, has had a portion devoted to paleontology. Not wishing to depart entirely from the custom of his predecessors, the writer has had the paper in question prepared by Dr. E. M. Kindle, who has for years made a specialty of this subject. A number of the species described and figured therein are new to science. Keys to the different species will help the beginner to properly classify any fossil which he is liable to find in the Devonian rocks of the State. The drawings, more than 300 in number, of the 31 plates accompanying the paper, were made especially for it by Dr. J. C. McConnell, of Washington, D. C. They represent, much better than words, the smaller details of the species described.

The clay manufacturing industry of Indiana has been growing very rapidly in the last three years. The reports issued by this Department in 1896 and 1898 contained special papers giving full details concerning the location, area and thickness of the valuable beds of shale and clay in the coal-bearing counties, as well as in the counties of the northwestern part of the State. Chemical analyses of many of the clays were also incorporated, and the uses for which the different deposits were best fitted were mentioned. As a result of this advertising much capital has been invested in the manufacture of clay products. At Brazil, the chief center of the industry, 15 factories have been or are being erected. A large factory which, for two or three years, has been months behind in its orders, is in operation just west of Terre Haute, and another is now being built a mile south to utilize a most valuable deposit to which attention was called in the 1896 report. Near Montezuma, two large factories have been erected since 1897 and some of the best deposits of fire-clay and shale north of Hillsdale have recently changed hands, the new owners proposing to erect factories during the coming year.

The demand for pressed front and ordinary brick, hollow brick, vitrified brick, sewer pipe, conduits, etc., is constantly increasing, and no place in the United States furnishes better facilities for the manufacture of such articles than does western Indiana. There raw ma-

terial of the best quality is plentiful and overlies the fuel necessary for its burning. Transportation facilities are excellent. These three factors present, competition can be defied.

Some of the best deposits, notably those near Mecca, Parke County, Clinton, Vermillion County, and several in the vicinity of Terrre Haute, Vigo County, are as yet undeveloped and offer most excellent opportunities to capitalists in search of investment. A large deposit of shale near Martinsville, Morgan County, has, by practical tests, been proven to make the best of pressed front brick and is well worthy of early development for that purpose, as the city of Indianapolis alone would absorb all the product.

PORTLAND CEMENT.

HISTORY—USES—COMPOSITION—PROCESS OF MANUFACTURE—METHODS OF TESTING, ETC.

By W. S. Blatchley.

A *cement* is any material which is capable of solidifying when in contact with water, without change of volume or notable evolution of heat. It differs from a *lime* in that the latter expands, crumbles and gives off heat when exposed to water. The presence of a clay more or less intimately mixed with a lime checks or stops the crumbling and evolution of heat, and brings about that hydraulicity, or power of slowly solidifying in water which characterizes a cement.

Natural Rock Cement.—If the lime and clay are mixed by nature; that is, if they occur already mixed in a stone which requires only quarrying, burning and grinding to form a cement ready for use, such a cement is termed a "Natural Rock Cement." The first cement of this kind made in the United States was in 1823 from a water lime-rock in Ulster County, New York. The hydraulic properties of this rock were discovered by accident. A canal was being constructed, and it was noticed that the lime which was burned from some of the strata hardened under water instead of slaking. Similar discoveries followed rapidly at other localities, and, as a result, the burning of natural rock cements soon became an industry of prominence. The stone from which this cement is made is termed water limestone, or hydraulic limestone. Vast beds of this stone, excellent in quality, occur in Clark, Floyd and other counties of Indiana bordering the Ohio River. In 1899 the total production of Natural Rock Cement in the United States was 9,868,179 barrels. Of this amount Indiana produced 2,922,453 barrels, valued at $1,022,858, or almost six times as much as any other State except New York, where the production was 4,689,167 barrels. A full account of the growth of

the Natural Rock Cement industry in this State, with details and statistics of manufacture, is given by Mr. C. E. Siebenthal in a subsequent paper in this volume.

PORTLAND CEMENT.—Where the materials or ingredients (lime and clay) entering into the cement are mixed artificially, then burned and ground, the resulting cement is termed Portland cement. This artificial cement was first made at Leeds, England, in 1824, by Joseph Aspdin, a bricklayer. He chose the name "Portland Cement" on account of the fancied resemblance in color and texture of the cement, when hardened, to the well-known oölitic building stone of Portland, England. Aspdin took out a patent for this cement, under date of October 21, 1824. His specification is for "An Improvement in the Modes of Producing an Artificial Stone," and is described as follows: "My method of making a cement or artificial stone for stuccoing buildings, waterworks, cisterns or any other purpose to which it may be applicable (and which I call Portland cement) is as follows: I take a specific quantity of limestone, such as that generally used for making or repairing roads, after it is reduced to a puddle or powder; but if I can not procure a sufficient quantity of the above from the roads, I obtain the limestone itself and I cause the puddle or powder, or the limestone, as the case may be, to be calcined. I then take a specific quantity of argillaceous earth or clay, and mix them with water to a state approaching impalpability, either by manual labor or machinery. After this proceeding I put the above mixture into a slip pan for evaporation, either by the heat of the sun or by submitting it to the action of fire or steam conveyed in flues or pipes under or near the pan, until the water is entirely evaporated. Then I break the said mixture into suitable lumps, and calcine them in a furnace similar to a limekiln till the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beat or rolled to a fine powder, and is then in a fit state for making cement or artificial stone. This powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar and thus applied to the purposes wanted."

It is difficult to recognize in this description a process likely to result in the formation of a cement of the present Portland type. It must be remembered, however, that Aspdin had a hard mountain limestone to deal with, and that probably the most easy way to obtain this material in a state of fine subdivision, in order to mix it with the clay, was to calcine it. It could then readily be slaked and reduced to powder. The next step was to temper it with the requisite amount of clay, and finally the mixture was submitted to a sec-

ond process of calcination. This double-kilning would, where fuel was relatively cheap, entail but little more cost and perhaps less labor than first grinding the limestone to fine powder under millstones and then mixing it with the clay, as is now done in the dry process of manufacturing Portland. Moreover, by the slaking action, the lime is obtained in an extremely fine state of subdivision, and therefore in a condition peculiarly well adapted for intimate admixture with the clay.

Aspdin fails to point out the exact amount of clay needed, rather an important matter in a specification, one would think, and he omits to state that the firing must be carried on until incipient vitrification is attained.*

The growth of the artificial or Portland cement industry was for many years very slow. In 1848 the son of the inventor formed a company and began the manufacture of the cement at Rotherhithe, near London. In a circular issued by this company it claims "that in consequence of improvements introduced in the manufacture, it will be found, for the following reasons, infinitely superior to any cement that has hitherto been offered to the public:

"(1) Its color so closely resembles that of the stone from which it derives its name as scarcely to be distinguishable from it.

"(2) It requires neither painting nor coloring, is not subject to atmospheric influences, and will not, like other cements, vegetate, oxidate, or turn green, but will retain its original color of Portland stone in all seasons and in all climates.

"(3) It is stronger in its cementative qualities, harder, more durable, and will take more sand than any other cement now used."

At the great exposition at Hyde Park in 1851, Portland cement was first brought prominently before the public, and tests were made showing its superior tensile strength, a crude form of the briquette now in such common use for testing, being, for the first time, used. Soon after this public exhibition of its qualities, its manufacture was begun on the Continent, where it gradually grew into enormous proportions, especially in Germany, that country for many years not only making its own supply, but exporting to the United States nearly two-thirds of the amount there used. Its manufacture also increased greatly in England where, at the present, it is made chiefly in the Thames and Medway districts, where white and gray chalk and river mud are used. In France the materials employed are marls, chalks, and clays. In Germany the more important centers of production are in the northern portion, especially the regions

* Redgrave—"Calcareous Cements," 1895, p. 25.

about Stettin and the Rhine Valley. Here, also, chalks and marls form the principal sources of the lime.

Portland Cement Industry in the United States.—Portland cement was first manufactured in this country in 1872, near Copley, Lehigh County, Pennsylvania, at a locality in which natural rock cement had, up to that time, been made. A second factory was soon after established at Wampum, Lawrence County, Pennsylvania, where the materials used were fossil limestone and clay.

On account of a lack of knowledge of the more technical processes of manufacture, as well as on account of the prestige which the foreign-made cement had secured among contractors and engineers, the growth of the Portland cement industry in the United States was very slow up to 1890. In that year the total output of the eighteen factories then in operation in this country was only 335,500 barrels, valued at $704,050. From 1890 to 1900 the growth of the industry in the United States was exceedingly rapid, and during the last half of this period almost phenomenal. The amount consumed in 1899 was very nearly three times that in 1890, while the imports have been reduced but slightly below what they were in 1891. The following table shows more graphically than words the increase by years in production and total consumption, as well as the variation in the amount imported:

COMPARISON OF THE DOMESTIC PRODUCTION OF PORTLAND CEMENT WITH THE IMPORTS.

(Barrels.)

	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.
Production in the United States	335,500	454,813	547,440	590,652	798,757	990,324	1,543,023	2,677,775	3,692,284	5,652,266
Imports	1,940,186	2,988,313	2,440,654	2,674,149	2,638,107	2,997,395	2,989,597	2,090,924	2,013,818	2,108,388
Total	2,275,686	3,443,126	2,988,094	3,264,801	3,436,864	3,987,719	4,532,620	4,768,699	5,706,102	7,760,654
Exports	....	....	21,536	14,276	9,725	83,682	85,486	53,466	36,732	110,272
Total consumption	....	3,443,126	2,966,558	3,250,525	3,427,139	3,904,037	4,447,134	4,715,233	5,669,370	7,650,382
Percentage of total consumption produced in the United States	....	13.2	18.4	18.2	23.3	25.4	34.7	56.8	65.1	73.9

From the table it will be seen that in 1897, the total increase in domestic production was 1,134,652 barrels, while the increase in consumption was 368,099 barrels. This was the first year that the increase in production was greater than that in consumption, and also the first year in which American manufacturers produced more than one-half of the Portland cement consumed in the United States.

According to Mr. S. B. Newberry, the acknowledged authority on Portland cement in this country, "This important step toward the replacement of imported by domestic Portland was largely brought about by the successful efforts of American manufacturers to produce a high grade product. Engineers in all parts of the country found to their surprise that the product of the leading American factories showed decidedly higher tests than the imported brands which had long been regarded as a standard. In fineness of grinding, also, the American cements were found superior to the imported. Nevertheless the fact remains that there is among contractors a considerable prejudice in favor of certain brands of German cements, and that the latter still command a higher price than the American. This prejudice is unfounded, and is therefore certain to depart in time, but it still exists. American cements can be made at a price which will allow them to be sold cheaper than the best imported German, and where the two come together in competition on large contracts the work is generally made to the American manufacturers on the basis of price. This was clearly shown on the letting of a large government contract at Pittsburg last winter. The offers were as follows:

One Belgium cement	$2 50 a bbl.
Five German cements, average price	2 60 a bbl.
Four American cements, average price	2 28 a bbl.

"The price of Portland cement is steadily coming down and the fall is being hastened greatly by the successful competition of American against foreign manufacturers. There can be no doubt that within a very few years practically all the Portland cement consumed in this country will be of domestic manufacture. The prices of some, however, will hardly be the same as they are now. When the demand is completely supplied by American manufacturers we shall have works in this country producing 2,000 barrels a day more than in Germany and the same result will be reached here as in Germany, namely, the complete replacement of the common natural rock cements by artificial Portland."*

* Brickbuilder, 1898, p. 108.

The following table shows the production of Portland cement by States in 1898 and 1899:

*PRODUCTION OF PORTLAND CEMENT IN THE UNITED STATES IN 1898–1899.

STATE.	1898.			1899.		
	Number of Works.	Product. (Barrels.)	Value, Not Including Packages.	Number of Works.	Product. (Barrels.)	Value, Not Including Packages.
Arkansas	......	....	....	1	50,000	$87,500
California	1	50,000	$100,000	1	60,000	120,000
Illinois	......	....	....	2	53,000	79,500
Indiana	1	2,500	4,375	......	....	....
Maryland	1	10,000	17,500	......	....	....
Michigan	2	77,000	134,750	4	342,566	513,849
New Jersey	2	587,163	1,027,535	2	892,167	1,338,250
New Mexico	......	....	....	1	1,500	4,500
New York	7	554,358	970,126	7	472,386	708,579
North Dakota	......	....	....	1	1,700	5,100
Ohio	6	265,872	465,276	6	480,982	721,473
Pennsylvania	8	2,095,141	3,142,711	9	3,217,965	4,290,620
South Dakota	1	31,000	62,000	1	35,000	70,000
Texas	1	8,000	24,000	......	....	....
Utah	1	11,250	22,500	1	45,000	135,000
Total	31	3,692,284	$5,970,773	36	5,652,266	$8,074,371

* From the article on Portland cement by S. B. Newberry, in the Twenty-first Annual Report of the U. S. Geol. Surv.

From this table it will be seen that the increase in production in 1899 was 1,959,982 barrels, or 53.1 per cent. This is the greatest increase in number of barrels of any year in the history of the industry in the United States, though the percentage of increase was greater in both 1896 and 1897, when it was respectively 55.8 and 73.5 per cent. That the domestic production has not been lessened by any decrease in the demand is shown by the table on page 5, where it will be seen that the imports since 1891 have been more than 2,000,000 barrels each year, while the imports for 1899 were 94,570 barrels in excess of those for 1898. In both 1898 and 1899 the demand in the autumn months was far in excess of the supply, and many important engineering works were suspended or delayed on

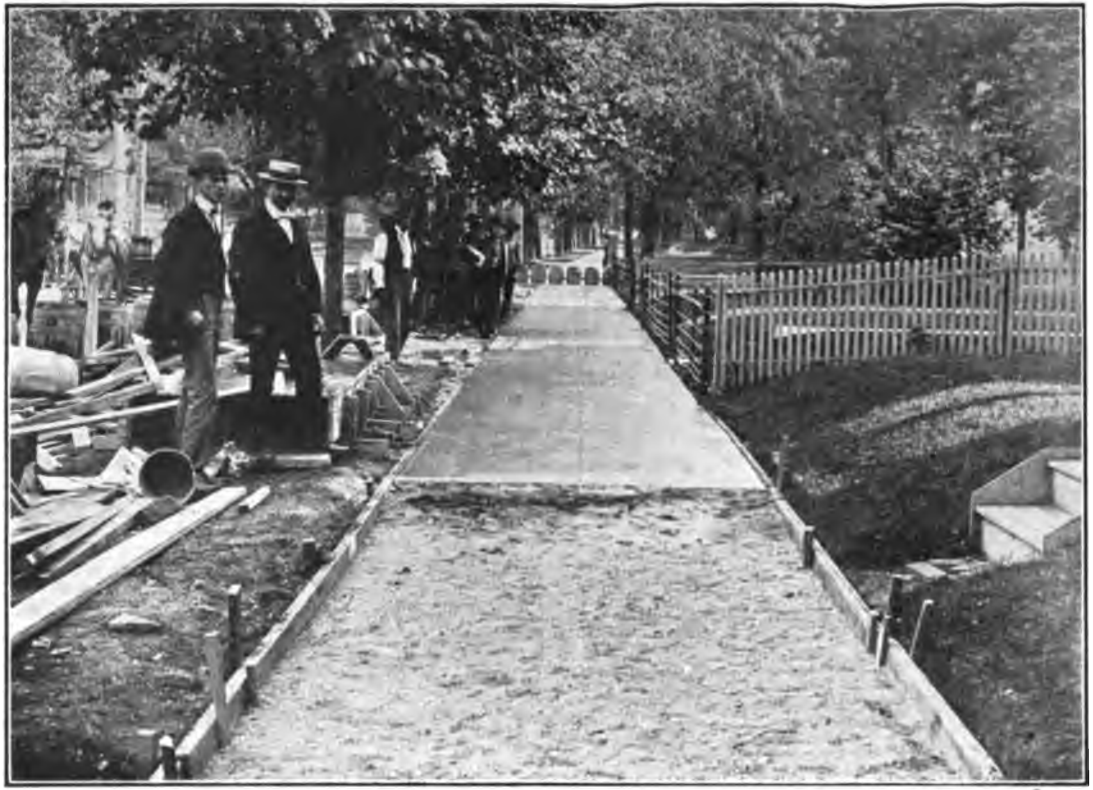
account of the impossibility of securing the cement. A number of factories had their output sold almost a year in advance, and high prices were paid in many instances for immediate shipment. The same condition existed in other countries, and as a result many new companies were organized and factories erected, both here and abroad, for the production of cement.

From the table it will also be seen that in 1899 the average price per barrel of 380 pounds, exclusive of cost of barrel, was $1.43. No data are available for securing the average price for 1900, but to the actual consumer, the price, even in large lots, was much higher. On the 10th of August, 1900, the Indianapolis Waterworks Company paid $2.37 per barrel in jute on board cars at Indianapolis for 4,000 barrels from an Ohio factory. On the other hand, a county surveyor was able to purchase, about the same date, a 700 barrel lot for $2.19 per barrel. The Whitehall Portland Cement Co., of Cementine, Pa., make a cement by the dry process from ground limestone and clay at a cost of 55 cents per barrel. Their plant is a very large one, costing over $700,000, and is fitted with the latest and most improved machinery. A careful estimate shows that the cost of making the cement, by the wet process, from marl and clay, including all general expenses, is, in such States as Michigan, Ohio and Indiana, about 66 cents per barrel; so that the margin of profit is still sufficiently high.

Uses.—One of the principal reasons for the great increase in consumption of Portland cement in this country in recent years is the discovery of many new uses for which it is especially fitted. Its list of possible uses has, in fact, more than doubled in the past five years. Soft and readily molded or shaped into any desired form when fresh; but if properly used, soon becoming harder and more durable than stone, impervious to moisture or vermin and perfectly fire proof, it is rapidly replacing not only stone, but also wood and iron for many purposes. In all great engineering enterprises it is being used to a far greater extent than ever before. Up to the present, and no doubt for many years to come, the demand has been and will be limited by the supply. As fast as new factories are established the market swallows up their product, and, up to the present, without effort or appreciable effect upon the price.

On account of its fireproof qualities and its imperviousness to moisture and vermin, Portland cement is especially suitable for the construction of all absolutely fireproof buildings, especially art galleries, museums, etc. The museum at Stanford University, California, now being erected, is a notable example of its kind. It will

PLATE 2.



ILLUSTRATING USES OF PORTLAND CEMENT.

Sidewalk of Portland Cement Concrete in Process of Construction on Meridian Street, Indianapolis, Ind.

be 300 feet in length, three stories in height, and the entire structure from foundation up—floors, walls and roof—will be of concrete and iron. The whole edifice is to be molded into a single monolithic structure without seam, joint or break. The bars of iron are embedded in the concrete and are immovably held at every point by the enveloping material, thus imparting their own tensile strength to the concrete, which obviates the necessity for great thickness or heavy weight. If the materials be mixed by machinery, the walls of a building can be built of concrete for 22 cents a cubic foot, more than 10 cents less than common brick work. For columns, cornices, doors, windows, and all moldings and ornaments its relative expense is at least from one-third to one-half less than that of cut stone as, after the moulds are made, the whole work can be done by unskilled labor. For any large public building designed to be fireproof, it is, therefore, the most economic material available.

Its use by railways for the construction of bridge piers, arch culverts, abutments, retaining walls, etc., is just beginning, and bids fair to assume enormous proportions. "Concrete culverts and bridge piers are particularly well adapted for use in the construction of new lines of railway, owing to the comparative ease with which the material for making concrete can be transported, as against heavy stone work. The use of derricks for loading and unloading material and specially constructed wagons for heavy hauling are not necessary in concrete work, and as it can be made with cheap, unskilled labor, a great saving in the wages of the force employed is thus effected. These culverts have a decided advantage over cast-iron pipes on new works owing to the great cost of transporting pipe."*

Especially will this increase in the use of Portland cement concrete become notable in the great Central Valley and Prairie States, where timber is becoming scarce or is wholly absent and where suitable stone has often to be transported for hundreds of miles. The increasing use of such concrete in these regions is but a natural economic development.

For breakwaters, large sewers, dams, piers, and other structures on and about the sea coast, great lakes, and larger streams of the country, concrete has no equal, either in durability or ease of transportation and construction. For railways and for national, state and municipal public works its growing consumption will be sufficient to utilize for many years, all the output of the many new factories which are proposed. Hence, while the growth of the Portland cement industry at this time is very rapid, there need be little fear

*F. G. Jonah in Canadian Engineer.

of an overproduction or of a failure to find an adequate market for the product.

The following is a partial list of the many uses to which Portland cement, or concrete made largely from this cement, is now being put:

USES OF PORTLAND CEMENT.

Abutments.
Arched culverts.
Artistic tile for inside decoration.
Artificial stone columns.
Asphalt pavements.
Bank vaults.
Cellar bottoms.
Chimneys, especially the tall ones of factories and mills.
Concrete sidewalks.
Curbs and gutters.
Dams and wheel pits in water powers.
Dry docks.
Engine beds.
Fence posts.
Fireproof floors.
Fortifications.
Foundations and walls for all fireproof buildings.
Foundations for brick and other street pavements.
Grain elevators.*
Irrigation flumes.
Lining of war vessels.
Locks of canals.
Mill races and water courses in general.
Monolithic concrete construction in general.
Pier, quay and breakwater construction.
Piling.
Pipe mains.
Railway ties.†
Reservoirs for water supply of cities, for sewage, etc.
Retaining walls for wharfs and embankments.
Sewers.

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*The Interior Elevator Co., of Minneapolis, Minn., will soon erect a large grain elevator for Duluth, to be constructed entirely of steel and Portland cement concrete, such as is in use on the Danube in Europe. The estimated cost for this elevator is nearly $1,000,000.

†Concrete railway ties are coming into use in Europe and oriental countries; and it will be but a few years until they will be extensively used in the United States.

PLATE 3.

Illustrating Uses of Portland Cement.

Sidewalk of Portland Cement Concrete Completed, on Meridian Street, Indianapolis, Ind.

Shingles and tiles for roofs.*
Stairways in public and private buildings.
Stuccoing for the exterior of old brick and frame buildings.
Terra-cotta blocks.†
Tunnel linings.
Vaults and burial tombs.

Germany, with a population of 50,000,000, manufactures about 18,000,000 barrels of Portland cement each year. Its exports are a little over 3,000,000 barrels, leaving 15,000,000 barrels for home consumption. The United States, with a population of 75,000,000, consumes about 7,650,000 barrels per year. The consumption per capita is therefore three times greater in Germany than in the United States. On account of the far greater magnitude of the engineering and railway operations in the United States there is little doubt but that the consumption of Portland cement will increase until it exceeds, per capita, that of Germany.

COMPOSITION.—The essential ingredients or elements entering into Portland cement are calcium, silica and aluminum. The calcium is furnished either by a limestone or marl; the silica and aluminum by clay. In the process of burning, these three elements unite to form a complex silicate. It is therefore necessary that they be combined in the proper proportions if the best results are to be obtained. In a few places in the United States, notably the Lehigh Valley region, Pennsylvania, natural deposits of stone occur in which the elements of Portland cement are found already existing in the proper proportions. It is in this region, comprised within a circle of fifteen miles radius, that the greatest development of the industry in the United States is found. There are at present in this region eleven factories, two of which are larger than any others in the world. One of these is producing over 8,000 barrels per day, while 4,110,132 barrels, or nearly four-fifths of the entire product of the United States, was produced by the eleven factories in 1899. In the rock of the Lehigh Valley region there is a slight excess of clay; a small proportion of pure limestone is therefore ground with the rock to produce a correct mixture.

In other places a pure limestone and clay are ground together for the cement. In this case the grinding of the stone must be much finer than where the natural Portland cement stone is used, since any coarse particles of the latter which may remain in the raw

* In Germany 40 per cent. of the burnt clay roofing tile has been replaced by concrete tile during the past 10 years.

† These blocks, made of concrete and molded in imitation of terra cotta, are being extensively used for external walls of dwellings and business houses.

material are of nearly correct composition. The use of marl as the form of carbonate of lime has greatly increased in the past few years, the new factories which have been erected in Michigan, Ohio and Indiana generally using that material. The following table gives the comparative product of Portland cement from limestone and marl for the years 1897, 1898 and 1899:

	1897.		1898.		1899.	
	Number.	Product.	Number.	Product.	Number.	Product.
		Barrels.		*Barrels.*		*Barrels.*
Factories using limestone	18	2,282,126	20	3,112,492	24	4,697,722
Factories using marl	11	395,649	11	579,792	12	954,544
Total	29	2,677,775	31	3,692,284	36	5,652,266

The chemistry of Portland cements has been very carefully studied by Messrs. S. B. and W. B. Newberry who, from a long series of experiments, have deduced the following conclusions:*

"First. Lime may be combined with *silica* in the proportion of three molecules to one, and still give a product of practically constant volume and good hardening properties, though hardening very slowly. With three and one-half molecules of lime to one of silica the product is not sound, and cracks in water.

"Second. Lime may be combined with *alumina* in the proportion of two molecules to one, giving a product which sets quickly, but shows constant volume and good hardening properties. With two and one-half molecules of lime to one of alumina the product is not sound.

"Assuming that the tri-silicate and di-aluminate compounds above mentioned are the most basic compounds which can exist in good cements, we arrive at the following general formula for cements:

$$(X\,(3CaO.SiO_2) + Y\,(2CaO.Al_2O_3),$$

in which X and Y are variable quantities, having different values according to the relative proportions of silica and alumina present in the clay employed.

"The formula $3CaO.SiO_2$ corresponds to 2.8 parts of lime, by weight, to one part of silica.

"The formula $2CaO.Al_2O_3$ corresponds to 1.1 parts of lime, by weight, to one part of alumina.

*"The Constitution of Hydraulic Cements," 1897, p. 7.

"Substituting weights for equivalents, we have the following formula, representing the maximum of lime which should be present in a correctly balanced cement:

"The per cent. of lime = the per cent. of silica × 2.8 + the per cent. of alumina × 1.1.

"This formula may be used to calculate the proportion of lime which should be used with any clay of known composition as follows: *Multiply the percentage of silica by 2.8, and the percentage of alumina by 1.1; add the products; the sum will be the number of parts of lime required for 100 parts clay.*

"As 2.8 parts lime correspond to 5.0 parts carbonate of lime, and 1.1 parts lime correspond to 2.0 parts carbonate of lime, the calculation may take the following simple form: *five times the percentage of silica, plus twice the percentage of alumina, = the number of parts of carbonate of lime required for 100 parts of clay.*

As a practical example of the use of this formula, let us suppose a clay of the following composition:

Silica	65.4
Alumina	16.5
Iron oxide	6.1
Lime	2.2
Magnesia	1.9
Moisture, combined water, etc.	7.9
Total	100.0

"Let us now calculate the amount of lime (or carbonate of lime) which must be added to this clay to produce a correct cement mixture:

$$\begin{array}{lr}
\%\ \text{Silica} = 65.4 \times 2.8 = & 183.12 \text{ lime.} \\
\%\ \text{Alumina} = 16.5 \times 1.1 = & 18.15 \text{ lime.} \\
\hline
\text{Total} \ldots\ldots\ldots\ldots & 201.27 \\
\text{Less lime contained in clay,} & 2.20 \\
\hline
 & 199.07
\end{array}$$

Therefore 199.07 parts of lime are required for 100 parts of clay.

"As 56 parts of lime correspond to 100 of carbonate of lime, we have

$$\frac{199.07}{56} \times 100 = 355.5.$$

Therefore 355.5 parts of carbonate of lime are required for 100 parts of clay.

"The correct mixture would then be:

100 parts clay.
355.5 parts pure carbonate of lime.

"The percentage of carbonate of lime in this mixture would be 78.0. On burning this a cement of high quality will result, provided the materials are finely ground and perfectly mixed. This statement was confirmed by practical test; an excellent cement of constant volume resulted.

It will of course be understood that the proposed formula represents the *maximum* of lime which can be used with safety. This maximum can be reached in practice only by most thorough grinding and mixing of the raw materials. In practice the preparation of the materials is always imperfect, and a certain part of the silica and alumina present remains inactive, as is shown by the occurrence of a small percentage of insoluble matter in all commercial cements. For this reason the proportion of carbonate of lime is usually carried about one to two per cent. lower than that called for by the above formula."

According to Dr. Michaelis, the ratio of the total silicates to the lime should be about as 1 to 2, and the variation from this ratio should only be within narrow limits. Cements rich in lime set more slowly, but harden to a greater degree than those poor in lime. Cements rich in silica generally set more slowly than those rich in alumina, but the former harden very quickly and are better for use in contact with ocean water. The celebrated German Portland cement manufactured at Stettin has a silica percentage of nearly 25 per cent. with 5.7 per cent. of alumina and 2.5 per cent. of ferric oxide.

From a series of experiments the Messrs. Newberry concluded that:

"Iron oxide (Fe_2O_3) combines with lime at a high heat, and acts like alumina in promoting the combination of silica and lime. For practical purposes, however, the presence of iron oxide in a clay need not be considered in calculating the proportion of lime required," and that "alkalies, so far as indicated by the behavior of soda, are of no value in promoting the combination of lime and silica, and probably play no part in the formation of cement."*

In regard to the alkalies, the German chemist, Schoch, expresses the opposite opinion from the Newberrys, and considers that these alkalies act as a flux and are of great benefit in connection with the

*Loc. cit., p. 16.

hardening process of cement, as they convert the silica into a soluble condition so that it combines readily with the lime when wet. Since these alkalies act so powerfully in bringing about the vitrification of clays in the burning of such products as sewer pipe and paving brick, there can be but little doubt that they have a somewhat similar effect, or at least lend much aid to the proper calcination or vitrification of the slurry or cement material during its progress through the kilns.

The question of the influence of magnesia as one of the ingredients of Portland cement has been studied by many chemists, but is, as yet, unsettled. It is held by several prominent authorities that the presence of any considerable amount of magnesia causes the cement to expand and crack after a time. R. Dykerhoff, a German authority, claims that more than four per cent. of magnesia, either added to a normal mixture or substituted for an equivalent percentage of lime, causes a steady deterioration in the strength of the resulting cement. Actual cracking was observed only when 8 per cent. or more of magnesia was present. The Messrs. Newberry, by a series of tests, found that pure magnesia, when calcined at a high temperature, sets with water and hardens like cement but is not constant in volume. Compounds of magnesia with alumina and silica did not set or harden in air, water or steam. When calcined with clay, the magnesia decomposes the clay, but the action is far less complete than in the case of lime; and the product of calcination had no setting or hardening properties. Magnesia is not capable of replacing lime in cement mixtures, the composition of which should be calculated on the basis of the lime only. On the whole it is believed that two and a half per cent. of magnesia is the maximum amount which a good grade of Portland cement can contain, though some German products contain as high as three and a half per cent.

Sulphur is another element which is harmful to cement, especially when the latter is exposed to sea water, as its presence in any quantity hastens disintegration. The source of the sulphur may be either calcium sulphate in the marl or clay, or iron sulphide in the coal used as fuel. An addition of one-third to three-fourths per cent. of fluorspar is often very beneficial for bringing about an easy clinkering of the material in the kiln.

The clay used in the making of Portland cement should not contain an excess of sand or free silica. Many clays contain a high percentage of sandy particles not in combination with the other elements. Such clays possess a harsh, gritty feeling when rubbed between the finger and thumb or when brought in contact with the tongue and it is possible to wash out from them a considerable quan-

tity of grains of sand. These clays, though well adapted for brick making, are not suitable for cement.

The clays best adapted for Portland cement are fine grained and have a greasy or unctuous touch; any free sand present must be removed or ground fine. The amount of silica in the clay used in the best grades of cement runs from 58 to 65 per cent. The more amorphous silica present, the better the clay. The amount of iron oxide present should not exceed 10 per cent. Clays low in iron are usually of a gray or blue color and change to light yellow when weathered.

The following are the analyses of some of the clays used in the making of European and American Portland cements:

	1	2	3	4	5	6	7	8	9	10
Silica (SiO_2)	60.06	59.25	60.00	62.48	64.72	64.70	62.10	69.49	56.54	57.98
Alumina (Al_2O_3)	17.79	23.12	22 22	20.00	24.27	11.90	20.09	16.42	19.43	18.26
Ferric Oxide (Fe_2O_3)	7.08	8.53	8.99	7.33	7.64	9.90	7.81		4.83	4.57
Lime (CaO)	9.92	......	4 18	6.30	1.89	.9	.65	2.29	7.27	1.75
Magnesia (MgO)	1.89	2.80	1.60	1.16	......	.7	.96	.78	3.05	1.83
Potash (K_2O)	2.50	1.87	1.49	1.74	1.90	......	......	....	......	......
Soda (Na_2O)	.73	1.60	.72	.37	2.10	......	......	....	......	......
Calcium sulphate ($CaSO_4$)	.60	2.73	.89	.60	......	......	.49	....	......	1.28

The above clays are used in making cement at the following localities:

Europe.

1. Province of Saxony.
2. Vorpommern.
3. Oberharz.
4. Brandenburg.
5. Medway.

America.

6. Sandusky, Ohio.
7. Bronson, Michigan.
8. Wellston, Ohio.
9. Stroh, Indiana.
10. Yankton, South Dakota.

It will be noted that the percentage of alumina in the above clays ranges between 11.90 and 24.27 per cent. Cements low in lime and without an excess of alumina but high in silica are always of low tensile strength. If the alumina in the cement runs above 8 per cent. it is considered high, if below 5 per cent., it is very low. Since the clay is the source of all the alumina, and almost all of the silica, too great an amount of clay will cause the resulting cement to fuse too easily. It will also be light in weight, will set quickly, have a brownish color and never become thoroughly hard. Moreover, it will crumble to a greater or less degree when exposed to the weather. On the other hand cements containing too great a percentage of lime will stand the hottest fire without fusing. When burned, such cements are slow setting, hard to grind, and liable to flow and swell after being used. In most of the Portland cements now on the market the lime runs from 60 to 65 per cent.

The following is a table of chemical analyses of some of the leading makes of European and American Portland cements:

	Dykerhoff. (German)	Germania. (German)	Porta. (German)	Empire. (American)	Saylor's. (American)	Sandusky, O. (American)	Bronson. (American)	Diamond. (American)
Lime (CaO)	63.06	63.72	62.28	60.92	62.30	64.19	63.17	61.90
Silica (SiO_2)	20.64	22.08	22.69	22.04	22.68	23.20	20.95	21.80
Alumina (Al_2O_3)	7.15	6.84	7.30	6.45	6.71	7.03	9.74	7.96
Iron Oxide (Fe_2O_3)	3.69	3.36	2.87	3.41	2.35	2.41	3.12	4.95
Magnesia (MgO)	2.33	1.32	1.08	3.53	3.14	.97	.75	1.61
Sulphuric Acid (SO_3)	1.39	1.82	1.62	2.73	1.88	1.05	.86	.79

The table shows that the composition of the Portland cements now on the market is very uniform, the limit of variation of each constituent in the analyses given above being less than three per cent.

PROCESS OF MANUFACTURE.—In the making of Portland cement from marl and clay, the process now followed in most of the factories in Ohio, Michigan and Indiana is what is known as the "wet process," the materials, after being carefully proportioned and thoroughly mixed being introduced into the kilns in a moist or semi-moist condition. "To accurately proportion the raw materials and to perfect an intimate mixture of them are the prime factors in making good Portland cement. Other things being equal the more exactly the proportions are maintained the greater the uniformity of the cement; the more homogeneous the mixture and the finer the state of division of its particles, the greater the strength and hydraulic energy of the product."*

In some plants the mixing is begun in large steel wet pans having a diameter of eight to ten feet, water being allowed to flow onto the ingredients while they are being ground. From the wet pans the mixture is pumped or forced through steel pipes into ball mills where the particles of clay and marl are brought into still more intimate connection. From the ball mill the mixture or "slurry," as it is now called, is passed into revolving steel kilns.

In other plants the clay is first passed through horizontal cylindrical steel dryers, where it is brought into direct contact with hot air, and then through a Williams or other grinding mill, where it is thoroughly pulverized. From these mills it passes into steel storage bins, and from there, as needed, into pug mills, which correspond to

*Lewis, Mineral Industry, 1897.

the wet pans above mentioned, where it first comes in contact with the wet marl. From the pug mills the mixture goes to the ball mills, which it leaves as slurry ready for the kilns.

The kilns in operation in all of the more modern factories are those of the rotary steel pattern, in which the process of burning is continuous. These kilns were first introduced into the United States in 1889 and crude petroleum was employed for fuel. The oil was blown in by jets at one end and the smoke and gases of combustion passed into a stack at the upper end of the inclined revolving cylinder. As a labor saving device, this kiln had many advantages over the old fashioned, upright intermittent kilns. For a number of years, however, it was handicapped by the varying price of the crude petroleum used as fuel. When this petroleum was only 37 to 48 cents a barrel, as it was between 1891 and 1894, and again in 1897, its use as fuel in cement manufacture was extensive, but when the average price rose above 60 cents, as in 1895 and 1896, and from 1898 on, the cost became prohibitory. Then it was that experiments were made with pulverized coal, and owing to various improvements in its preparation and in the methods of feeding it into the furnace, it is rapidly becoming adopted as a cheap and in every way satisfactory fuel for use in rotary kilns. At the same time the evolution of the mechanical features for handling both the raw materials and burned product in the rotary kiln plants has steadily advanced. As a consequence the amount of manual labor necessary has been materially reduced and the cost of the manufactured product correspondingly lowered. So satisfactory have these results been that in 1899, 20 of the 36 factories in the United States were using the rotary kilns, and in that year 3,711,220 barrels, or 65.7 per cent. of the total production was burned in these kilns, as against 149,000 barrels, or 25.2 per cent. so burned in 1893.

The rotary kilns in use vary in size, some being 60x6 feet with a capacity of 160 barrels per 24 hours; others 60x5 feet, with a capacity of 125 barrels. They are so set that the back end is a foot or two higher than the lower or front end. The coal used is bituminous and usually a mixture of slack and nut. In some factories it is dried in upright steel dryers encased in brick, the hot air being applied between the brick and the steel, and then ground in revolving tube mills; in other factories it is dried in rotary cylinders about 4x50 feet in size, and afterward ground in Griffin or similar mills. After grinding it is conveyed to storage tanks. In the latest and most improved plants, these are flat funnel-form, made of heavy sheet iron, one being fastened to the walls about six feet above the

ground, and in front of each rotary kiln. The coal, when prepared as described, is in the form of a fine powder, and is forced by a blower into the front end of the kiln, where it burns like gas, evolving a heat of 3,000 to 3,500 degrees F.

The raw material or slurry mixture enters the kiln by a spout at the upper end and is carried slowly forward and downward by the revolution of the furnace, the burnt clinker finally falling out of an opening at the front end just below the point at which the fuel is forced in. In burning, the furnace is at a white heat 20 to 25 feet back from the front, and at a red heat 10 to 15 feet back. The material, in passing through, is kept at a high heat only 15 to 20 minutes, although it is in the kiln about three times as long. It emerges in clinkers the size of a hickory-nut or less. These are lifted by endless bucket elevators and are then stored in steel cooling bins, or are passed through troughs of water and so cooled immediately. In some factories it is customary to add about two per cent. by weight of raw ground gypsum to the cooled clinker to prevent the cement from setting too quickly.

From the cooling bins or troughs the clinkers go to the final grinding machines. These are either of the Griffin or the ball and tube pattern, and from them the cement emerges as a finished product. From these mills it is conveyed to the storage bins where it is usually kept 60 days or more before being shipped for consumption. This seasoning increases the tensile strength by neutralizing the free lime remaining in the cement.

From what has been written it will be seen that the manufacture of Portland cement is an operation requiring great care and skill. The selection, preparation and mixing of the raw materials, the burning of the charge, and the sorting and grinding of the product, must all be carefully controlled, or serious defects in the finished product will result. The faults shown by bad cements are, moreover, generally not trifling ones, nor immediately evident, but often consist of hidden and dormant evils, which may cause the failure and destruction of important pieces of engineering work after the lapse of months or years. It is evident, therefore, that simple and rapid methods of detecting these hidden faults, and of determining the comparative values of different samples of cement, are absolutely indispensible to all engaged in the many kinds of constructive work in which cement is used.

The Testing of Portland Cement.—Each of the leading factories now has, as an adjunct to its plant, a laboratory in which an experienced chemist is constantly at work, making analyses of the raw

materials and the completed product, and also carrying on numerous tests to show the setting and hardening properties, the tensile and compressive strength, and the permanence in water and air of the cement manufactured. Each of the great engineering departments of the different nations, as well as those of different cities, have certain special requirements or specifications which each brand of Portland cement offered must satisfactorily meet before it will be accepted for use. The requirements vary much, and are based not only upon the special use to which the cement is to be put, but also, oftentimes, upon the whim or judgment of the engineer in charge. Some engineers require only a proper tensile strength to be shown. Others require satisfactory proof of many qualities other than those above mentioned. The following are the

SPECIFICATIONS OF THE ENGINEERING DEPARTMENT, DISTRICT OF COLUMBIA.

Fineness.—Not less than 95 per cent. to pass a 50 mesh sieve, and not less than 85 per cent. to pass a 100 mesh sieve.

Time of Setting.—Initial set in not less than one hour.

Tensile Strength.—One day, neat, 125 lb.; 7 days, neat, 400 lb.; with three parts sand, 100 lb.; 28 days, neat, 500 lb.; with three parts sand, 150 lb.

Constancy of Volume.—Portland cement shall not contain more than 3 per cent. of free lime, and shall withstand without cracking a temperature of 212 degrees F. after immersion in water for 24 hours.

The city of Philadelphia in 1898, required only a test for tensile strength as follows:

Neat—24 hours, 180 pounds.
7 days, 500 pounds.
28 days, 600 pounds per square inch.
One part cement to three parts sand—
24 hours, 100 pounds.
7 days, 170 pounds.
28 days, 240 pounds per square inch.

The chief standards of reference among American engineers for the testing of Portland cement are the recommendations of the American Society of Civil Engineers, drawn up by a committee appointed to devise a uniform system of testing. The report of this committee, published in the proceedings of the society for June, 1885, contain, among others, the following important recommendations:

"Fineness.—Cement of the better grades is now usually ground so fine that only from 5 to 10 per cent. is rejected by a sieve of 2,500 meshes per square inch (50 mesh). The finer the cement, if otherwise good, the larger dose of sand it will take, and the greater its value.

"Checking or Cracking.—Make two cakes of cement, two to three inches in diameter, one-half inch thick, mixed with water to the consistency of stiff plastic mortar. Note the time required to set hard enough to stand the wire test recommended by General Gilmore, 1/12 inch diameter loaded with ¼ pound, and 1/24 inch diameter loaded with 1 pound. One of these cakes, when hard enough, is placed in water and examined from day to day to see if it becomes contorted or cracked. The remaining cake should be kept in air and its color observed.

"Tensile Strength.—The cement is to be tested neat and also with three parts sand. The amount of water required is approximately as follows: Neat Portland cement, 25 per cent.; cement with one part sand, 15 per cent. of total weight; with three parts sand, 12 per cent. The mixing must be rapid and thorough; the mortar, which should be stiff and plastic, should be firmly pressed into the molds with the trowel, without ramming, and struck off level.

"The temperature of the briquettes and of the testing room should be constant between 60 and 70 degrees F.

"The sand recommended is the *crushed quartz* used in the manufacture of sandpaper, of such fineness as to pass a 20-mesh sieve and be caught on one of 30 meshes."

The tests for tensile strength are made with small molded briquettes which are in shape somewhat like the figure 8. The following method of making the cement and sand briquettes is that adopted by the German Minister of Public Works and is probably the best in vogue: For five briquettes weigh out 250 g. (9 oz.) cement and 750 g. (27 oz.) sand. Mix dry, add 100 c. c. water (3½ oz. by weight = 10 per cent.) and work strongly five minutes. The mixture is pressed into the molds so as to fill them above the top, and pounded for at least one minute each with an iron spatula, at first gently from the sides, then more strongly, until the mass becomes elastic and water appears on the surface. The spatula should be 14 inches long, the blade 1⅛ by 2 inches, and should weigh about 250 g. (9 oz.). Briquettes are to be kept in a zinc lined box for 24 hours, and then placed in water. Tests are to be made at seven days, 28 days and 12 weeks, and all tests are to be made immediately on taking the test pieces from the water.

The testing machine in most common use is one made by the Fairbanks Scale Co., in which the weight is applied by a stream of shot which runs from a reservoir into a pail suspended at the end of the steel-yard arm; when the briquette breaks the arm falls, automatically cutting off the flow of shot. The actual weight used is multiplied by 100. The time required to break a briquette is about five seconds for every 100 pounds of tensile strength.

Mr. S. B. Newberry has issued a little pamphlet entitled "Notes on Cement Testing" which contains valuable information based upon the results of his experience. In regard to the making of briquettes and the constancy of volume of the cement he makes the following observations:

"The proportion of water used greatly affects the resulting strength. Enough water should be taken to make a stiff, plastic mixture; more than this weakens the briquettes, especially when tested at short periods. Portland cement requires from 22 to 25 per cent. In work so necessarily exact as this, the use of French weights and measures will be found an immense saving of labor and tedious calculation. The cement and sand are weighed in grammes and the water measured in cubic centimeters. Since one cubic centimeter of water weighs one gramme, the correct percentage may at once be taken without calculation.

"The thoroughness of mixing the cement and water makes a most surprising difference. The German requirements specify that the mixture for sand briquettes shall be 'strongly worked with the trowel for five minutes.' The writer found, in one case, that a cement with three parts of sand, worked about one minute, gave at seven days 87 lbs.; the same mixture, thoroughly worked five minutes, gave in seven days 240 lbs. With neat cement thoroughness of mixing is equally necessary. Doubtless many failures and variations in results are due to neglect of this precaution. Rubbing the moist mixture in a large porcelain mortar for a few moments before filling each mold is practiced by some. This method gives higher results, and, if adopted, should be uniformly followed.

"Constancy of Volume.—The tendency of cement to expand or crack is the most dangerous of all the faults it can show, since this may in time cause the destruction of the work in which the cement is used. The pat test on glass is generally relied upon to detect this fault, and should never be omitted. Care should be taken not to put the pats in water until thoroughly set, as the best cements will fail if put in water too soon. For the sake of uniformity it is best to keep the pats for 24 hours under a damp cloth or in a closed box be-

fore putting in water. The amount of water used in mixing should not be too great, or the cement will not harden well. The amount specified in the German requirements will be found suitable. The cracks due to expansion occur usually at the edges of the pat, and radiate from the center. These should not be confused with irregular shrinkage cracks, which show themselves when the pats are made too wet and allowed to dry out too much during setting.

"The tendency to expand and crack shows itself much sooner and more distinctly in the pats than in briquettes. Nevertheless the inspection must be continued for a long time, if all possibility of future failure is to be avoided. The writer has known cases in which the pats stood satisfactorily for two weeks or more, but briquettes of the same cement went to pieces after several months. The dangerous expansion of cement is due to free or imperfectly combined lime, resulting generally from coarseness or imperfect mixture of the raw materials. The slaking of this lime is often very long delayed, but finally takes place with irresistible force, completely destroying the hardened cement and the work done with it.

"For the purpose of quickly determining any tendency of cement to expand and crack, the boiling test is largely used. This consists in exposing the pats, after setting, to the action of steam for several hours, then placing them in boiling water for some hours more. The action of steam quickly slakes the free lime, if present, causing the pats to swell, crack and often fall to powder. The writer believes that three hours' exposure to steam is amply sufficient for all practical purposes, and that the boiling water test is unnecessary. A few trials will convince anyone that no cement which cracks in cold water, even after months, can possibly stand the test in steam for three hours. The fact is that no cement is wholly free from uncombined lime, and that a very small percentage of this is entirely harmless. Such a proportion as would be dangerous in practical work is immediately and strikingly detected by the test in steam, and much more surely than by long tests in cold water.

"In using the hot test, care should be taken not to make the pats too wet, since excess of water causes even the best cements to swell up and soften under the action of steam. The writer has found that exposure to steam after setting is a more searching test than that of placing in steam as soon as made. In the latter case, slaking of the free lime appears often to take place before the setting, and the fault thus escapes detection. Pats of sound cement placed in steam after setting will harden rapidly, and show no cracking or crumbling; they will also generally remain attached to the glass,

though this point is usually not regarded as essential, since the best cements vary greatly in this respect."

Mr. Newberry also recommends the following as a fair equipment of the apparatus needed for testing cements:

A slab of slate or marble, at least two by three feet in size, one and a half inches thick.

A grocer's scale, weighing to one-fourth ounce.

Set of weights, preferably on the metric system.

A glass graduate for measuring water, preferably showing cubic centimeters.

A trowel with five-inch blade.

Pieces of glass, about five inches square, for pats, and some about three inches square for hot tests.

Testing machine and at least one dozen molds.

A trough for keeping briquettes in water, best lined with zinc.

A square copper box on legs for hot tests, with gas burner, rack for pats, and cover.

THE PORTLAND CEMENT INDUSTRY IN INDIANA.

The first Portland cement factory in Indiana, and one among the first in the United States, was erected at South Bend in 1877, Thomas and Duane Millen, father and son, with John H. Leslie,* being the founders. A factory had, a short time previously, been erected at Kalamazoo, Mich., for the making of Portland cement from marl and clay, but it was not a success. The South Bend factory was, therefore, the first in the United States to successfully use these ingredients in cement making.

The Millens and Leslie began experimenting in June, 1877, and, after making innumerable experiments in proportion and combination of different materials, and building a large number of experimental kilns, they succeeded so far that in the following October they began preparing a small plant to manufacture the cement for the market. They began with one small semi-dome kiln and one millstone with an American cracker to reduce the clinker for the millstone, thus requiring one man with a sledge and a large hollow piece of iron to do the work of a Blake crusher.

They did not succeed in successfully burning any clinker until the latter part of January, 1878, although they were working day and night to find the right proportion for the mixture, the proper

* To Mr. Leslie, still a resident of South Bend, I am indebted for many of the facts here given regarding the early history of the Portland cement industry in Indiana.

way to fill the kiln and the best kind and proper amount of fuel. At last these problems were solved and, with occasional set-backs, they succeeded so well that it was determined to construct another and larger dome kiln. The first year's operation lacked much of being profitable. The second year they constructed a second dome kiln and made many improvements in the methods of mixing, drying and burning, so that at the end of this second year they were nearly even with expense and profit.

The company was soon after reorganized by taking in Homer Millen, a younger son, under the firm name of Millen & Sons, and disposing of their other manufacturing interests, they gave their entire energies to developing their cement plant. The quality of the cement was gradually improved, and the United States Government finally recognized its high grade by annually purchasing large quantities for use in the arsenal at Rock Island, Illinois. The output was, however, small compared with that of factories of to-day, ranging from 5,000 to 20,000 barrels per annum. The cement was made from marl taken from the lakes at Notre Dame and from clay shipped from Bertrand, Michigan, seven miles north.

The analyses of the raw materials, made by H. H. Hooper of Chicago, were as follows:

MARL.

Calcium carbonate ($CaCO_3$)	91.25
Magnesium carbonate ($MgCO_3$)	3.21
Calcium sulphate ($CaSO_4$)	.24
Insoluble inorganic matter (silica, etc.)	3.80
Organic matter	1.50

CLAY.

Silica (SiO_2)	59.36
Alumina (Al_2O_3) and Iron Oxide (Fe_2O_3)	10.01
Magnesia (MgO)	2.40
Lime (CaO)	23.80
Sulphuric acid (SO_3)	1.71
Soda (Na_2O) and Potash (K_2O)	.58
Water (H_2O) combined	2.05

The clay was first ground in a disintegrator, then mixed with the marl in a pug mill in the proportion of one part to four. As it issued from the pug mill it was cut into cakes the shape of an ordinary brick, but larger. These were placed on iron cars and dried 24 to 36

hours by steam and were then burned in an English dome kiln,* four of which, averaging in capacity about 65 barrels of cement each, were in use by the company. These kilns were intermittent in operation. In preparing the kiln for burning, wood and coke were piled for several feet above the grate and then above that the bricks of dried slurry and coke in alternate layers up to the doors at the base of the stack. The doors were then sealed up, the fire started at the bottom and allowed to burn for 64 hours, until it had burned through the clinker at the top. The doors were then opened, and after cooling, the clinkers were removed, the kiln being recharged for another burning. This style of kiln consumes a large amount of fuel and requires more or less sorting of the clinker to separate the underburnt and vitrified material.

At the South Bend factory the clinkér, after burning, was run through a Blake crusher and reduced to the size of a hickory-nut or less; then through a "cracker" from which it emerged in pieces the size of a grain of wheat, and then through a rock emery mill for final grinding.

The cement of this factory for many years had a high renown among engineers and contractors. The average tensile strength of its neat briquette was as follows:

24 hours	225 pounds.
7 days	400 pounds.
28 days	550—625 pounds.

while its chemical composition showed the presence of

Lime (CaO)	59.24
Silica (SiO_2)	22.30
Alumina (Al_2O_3)	7.21
Iron Oxide (Fe_2O_3)	3.79
Magnesia (MgO)	3.03
Sulphuric acid (So_3)	1.47

In 1886 the original founders, Thomas and Duane Millen, opened up another and larger plant at Warner's, New York, leaving the one at South Bend in the care of Homer Millen and Mr. Leslie. These gentlemen succeeded in increasing the output several hundred barrels per year. The demand for their product continued to increase, so that from 1887 on, the company was constantly refusing orders during the summer and fall months. In 1889, the Millens,

*This style of kiln was the only one used in the United States up to 1889, and next to the rotary continuous, it is the most common one in operation to-day, the process of burning being the same as here described.

PLATE 4.

a

b

THE PORTLAND CEMENT INDUSTRY AT SOUTH BEND, INDIANA.

(a) One of the dredges used in securing marl from Notre Dame Lakes.
(b) The new factory erected in 1891.

desiring to concentrate their capital, sold their interests in Indiana to the South Bend Portland Cement Co., consisting of Horace M. Taggart and E. F. Marshall, Mr. Leslie being retained as superintendent. The new company was for two or three years very successful, being several carloads behind their orders during the cement season, although when the season opened they usually had from eight to ten thousand barrels in stock. Tiring at last of declining orders, they concluded to increase their capital stock by reorganizing and building a larger plant. This was begun in the summer of 1891, and late the next spring the new plant was completed at a cost of about $40,000. The machinery consisted of one large Blake crusher; one pug mill; one clay grinder; three sets of millstones; two 80 horse-power boilers; one 125 horse-power engine; three dry arches, fitted with pipes and cars; elevators, conveyers, line-shafting and all other necessary equipments. The burning was done in "dome" kilns of large size, four of which were erected. The plant was in operation only about 18 months, during which time its output was about 60 barrels daily.

Private misunderstandings and dissensions arising among the members of the company, the plant was shut down in 1893, and remained closed until 1896, when it was operated for a short time. Soon after its second opening the company failed, and the plant was permanently closed. It is understood that a Chicago company has recently purchased or leased it, and will use it in making Keene's cement.

The old factory, after having been idle for a year of two, was reopened by a new company in 1894. From a lack of experience the new owners were not able to make cement of as good quality as that produced by the original founders, nor were they able to compete with the lower-priced makes burned in continuous kilns. The output was, therefore, allowed to dwindle, and finally stopped in 1898, the factory having been idle since that year. The high standard attained by the product of the original company shows that the materials used were in every way suited for the manufacture of an excellent grade of Portland cement.

THE WABASH PORTLAND CEMENT COMPANY.—This company began the manufacture of cement at Stroh, Lagrange County, Indiana, in August, 1900. Their plant was erected in 1899 and 1900, on a piece of high ground between Big and Little Turkey lakes, a railway switch having been put in connecting the site with the Chicago Division of the Wabash Railway at Helmer,

five miles southeast. With the exception of the chemical laboratory and office, the whole plant is under one roof. It is equipped with the latest improved machinery as follows: One steel revolving dryer, 4x40, and Williams pulverizer for clays; one Vulcan dryer and Smith tube grinder for the reduction of the fuel coal to powder; four rotary continuous kilns, 60x5 feet in size, with a total daily capacity of 480 barrels; 20 steel tram cars, holding one and a half cubic yards each, to convey the marl from the pit to the mouths of the pug mills, three in number; three tube mills for thoroughly mixing the slurry after it leaves the pug mills; and four ball mills for grinding the cement. The capital invested in the plant is at present about $275,-000, though this will soon be increased by the addition of more rotary kilns and other machinery.

According to the statement of the chemist, Mr. W. R. Oglesbey, employed at the works, the average tensile strength of the cement being shipped from the factory in January, 1901, was as follows:*

Neat:	
7 days	700 pounds.
28 days	824 pounds.
One part cement to three parts sand:	
7 days	210 pounds.
28 days	302 pounds.

while its average analysis showed the following percentage composition:

Silica (SiO_2)	21.78
Alumina (Al_2O_3)	7.31
Iron oxide (Fe_2O_3)	2.65
Lime (CaO)	62.35
Magnesia (MgO)	2.88
Sulphuric anhydride (SO_3)	1.78
Carbonic anhydride (Co_2)	.23
Water (H_2O)	.55
Potash (K_2O), Soda (Na_2O) and loss	.47

THE SYRACUSE PORTLAND CEMENT COMPANY.—The Syracuse Portland Cement Co. began the erection of a plant by the side of the Baltimore & Ohio Railway, one-third of a mile east of Syracuse, Indiana, in 1899, and completed it ready for the making of cement in November, 1900. The materials used are marl from Syracuse Lake and clay from near La Paz, Indiana.

* An analysis of the clay and marl used will be found under the heading of Turkey Lake, Lagrange County, on a subsequent page of this volume.

The composition of the marl, clay and cement are as follows, according to S. B. Newberry, chemist:

	Marl.	*Clay (La Paz).*	*Cement.*
Silica	1.74	55.27	22.06
Alumina	.90	10.20	4.80
Iron Oxide	.28	3.40	1.66
Lime	49.84	9.12	65.44
Magnesia	1.75	5.73	3.82
SO_3	1.12	....	0.90
Loss	46.01	....	....

The different departments of the plant at Syracuse are in separate buildings, thus diminishing greatly the risk of loss by fire. At the same time the arrangements for carrying on the work are so perfected that no waste of labor or increase of machinery is necessitated by this isolation. The buildings erected and machinery installed are in part as follows: (1) Power house, with three sets of boilers; two compound engines of 1,000 horse-power each, and two Westinghouse dynamos each of 440 voltage power. The foundation and floors of this building, as of all the others, is of concrete, the engines being set on concrete foundations reaching to below the level of the water in the nearby lake. (2) Mixing room, 218x62 feet, containing four upright cylindrical storage tanks for marl and clay, each 16x15 feet; two 10-foot wet pans; two steel tube mills, 30x6, for mixing slurry; and three storage tanks 16x15, for slurry after mixture. (3) Rotary building, 100x110 feet, containing six rotary kilns, 60x6 feet, with a total capacity of 960 barrels daily, and six storage tanks, one in front of each kiln, for powdered coal. (4) Coal grinding house, 176x30 feet, containing two steel rotary dryers, each 47x4 feet, and four Griffin mills. (5) Dry grinding house, containing four ball mills and two rotary tube mills. (6) Warehouse, 147x60 feet, with packing room, 45x60, annexed. (7) Store building for supplies and machine shop. (8) Main office and chemical laboratory. The plant is one of the best equipped now in operation in the United States, the amount of capital invested being nearly $400,000. The company is composed mainly of Cleveland and Sandusky, Ohio, capitalists. Preferred stock amounting to $400,000, with a guarantee of 6 per cent. interest, and common stock to the amount of $700,000, was issued. Most of the available marl in and around Turkey or Wawasee Lake has been purchased by this company, and it has also secured, at a cost of $6,000, the only eligible site for a factory by the side of the B. & O. Railway, near Johnson's Bay, Turkey Lake.

Three additional companies have been organized for utilizing some of the Indiana marl deposits, hereinafter described, in the manufacture of Portland cement. These are as follows:

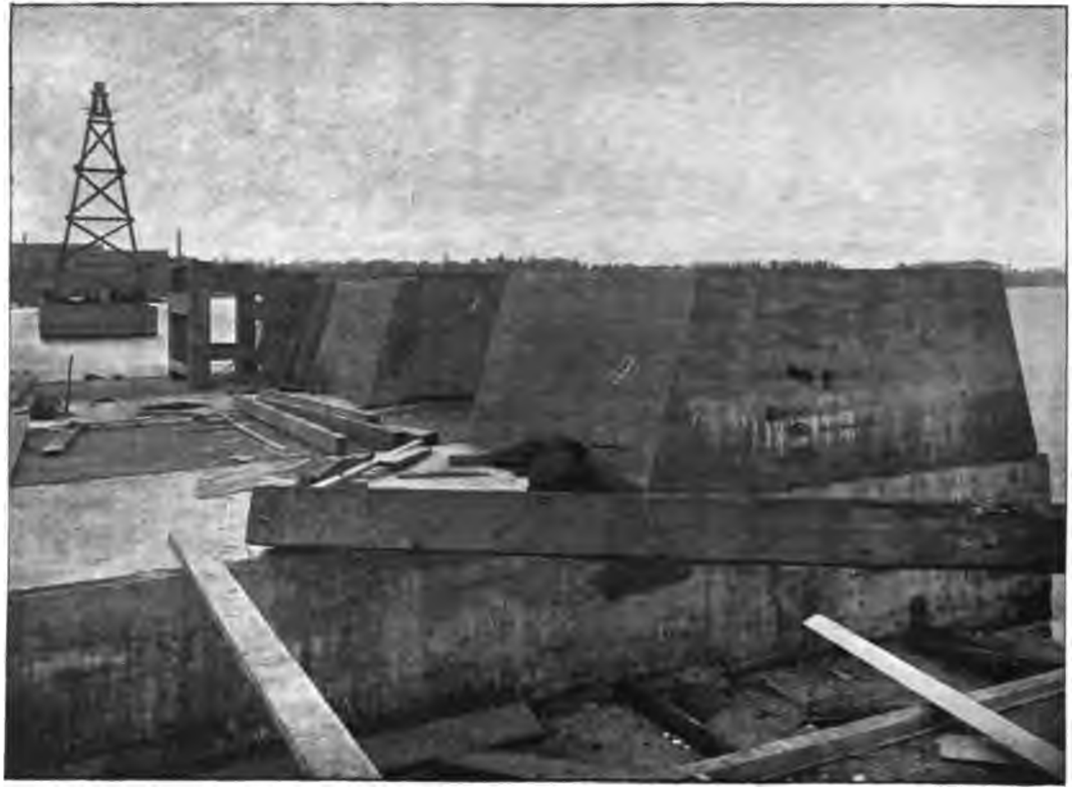
(1) The Indiana Portland Cement Co., with headquarters at Detroit, Michigan, has invested $12,000 in marl and clay lands in and around Dewart and Waubee lakes, Kosciusko County, and propose soon to erect a factory near Milford.

(2) The Goshen Portland Cement Co., at an expenditure of $11,600, secured control of 560 acres of marl land, the former sites of Mud and Cooley lakes, Elkhart County, and are now engaged in raising the funds necessary to erect and equip a large factory.

(3) The Monolith Portland Cement Co., with headquarters at Bristol, Elkhart County, has secured by purchase the extensive marl deposits in and about Indiana and Long lakes, north and northwest of Bristol, and will soon erect a large factory, utilizing the water power of the St. Joseph River.

From what has been written it will be seen that the citizens of Indiana have until very recently been exceedingly backward in utilizing the materials suitable for cement making which lie within her bounds. However, the two factories which have just been erected, and those which are proposed promise much for the future. Let us hope that they are but the forerunners, the pioneers of a great industry which shall center about the lakes and marshes of northern Indiana.

PLATE 5.



ILLUSTRATING USES OF PORTLAND CEMENT.

Nearly completed section of Government Breakwater at Cleveland, Ohio, made of Portland Cement Concrete.

THE

LAKES OF NORTHERN INDIANA

AND THEIR

ASSOCIATED MARL DEPOSITS.

BY W. S. BLATCHLEY AND GEO. H. ASHLEY.

INTRODUCTORY.

In the preparation of the present paper Dr. Ashley collected and partially wrote up the data on the marl deposits of the larger number of the lakes, and, with three exceptions, drew all of the accompanying maps. He also furnished a part of the data for the preliminary article on marl. Mr. Blatchley wrote the articles on "Lakes" and "Marl," and most of the matter pertaining to the individual lakes. He also edited and rewrote in part that portion of the marl data on these lakes collected by Dr. Ashley. Dr. J. T. Scovell, of Terre Haute, prepared most of the article on Lake Maxinkuckee and furnished the map of that lake. Mr. Hugh B. Holman, of Rochester, kindly made the survey and platted the map of Manitou Lake and Mr. George W. McCarter that of the Barbee Lakes, Kosciusko County.

The thanks of the authors are due to a large number of persons who kindly furnished information, and in other ways assisted in the collection of the data. Among those to whom special acknowledgments are due are Dr. Vernon Gould, of Rochester; Mr. J. P. Dolan, of Syracuse; Mr. George W. McCarter, of Warsaw; Capt. B. F. James, of North Webster; Mr. Frank Hay, of Winona, Starke County; Mr. Jacob Kellar, of North Judson; Mr. Walter Derr, of South Bend, and Mr. Earl E. Ramsey, of Muncie. Others are mentioned specifically in the body of the paper.

THE LAKES OF NORTHERN INDIANA AND THEIR ASSOCIATED MARL DEPOSITS.

By W. S. Blatchley and Geo. H. Ashley.

LAKES.

The lakes of northern Indiana are the brightest gems in the corona of the State. They are the most beautiful and expressive features of the landscape in the region wherein they abound. Numbered by hundreds, they range in size from an area of half an acre up to five and a half square miles. With the fertile soil, the great beds of gravel, and the myriads of bowlders, large and small, they are to be classed as mementos of those mighty ice sheets which, in the misty past, covered the northern two-thirds of our State. Outside of the counties in which they occur but few of the citizens of Indiana know of their presence, their beauty, their value. Their origin, their fauna and flora, the causes of their gradual diminution in size and final extinction are likewise known to but few.

By the red man these lakes were more highly appreciated than by his more civilized Caucasian successor, for the reason that the Indian stood much nearer to wild nature than we. On the higher ridges overlooking the lakes he had his village sites. Over their placid waters he paddled his birchbark canoe, and from their depths he secured with spear and hook fishes sufficient to supply his needs, while mussels and the roots of the water lily added variety to his daily food. Wild fowl by myriads, in their migrating seasons, came and went, stopping to feed upon the lakes, thus offering him many a chance to test his marksmanship with bow and arrow, while the skins of the muskrat, otter and beaver which he trapped about the marshy margins furnished him protection against the cold. Thus it will be seen that his very existence depended oftentimes upon these living bodies of water. It is little wonder, therefore, that he remained in their vicinity until driven westward by the conquering white man, leaving only the signs of his feasts—vast piles of shells, bones, and pit-ovens—as reminders of his former presence.

Of the two classes of glacial lakes existing in the United States, viz., those with *rock* basins and those with *drift* basins, only the latter are found in Indiana. The original bottom of these is composed of an impervious clay, or mixture of clay and gravel, which is probably nowhere much less than 100 feet in thickness. Upon this bottom has been deposited, during the centuries which have elapsed since the lake was first formed, thick beds of muck, silt or marl. The cause and manner of this deposition will be noted farther along. Here it is only necessary to say that it began the day the lake came into existence, has been continuous since, and will go on until the lake becomes wholly extinct. In other words, the water of all these glacial lakes was much deeper when they were first formed than now.

The lakes of Indiana all owe their origin to the irregular deposition of the drift brought in by the glaciers. The original hollows or lake basins are the counterparts and complements of the surrounding hills and knobs so characteristic of the terminal moraines of the retreating ice sheets. They occur only in the three northern tiers of counties of the State, and are found, for the most part, in the great interlobate moraines which lie between the former borders of the Michigan, Saginaw, and Erie ice lobes.

Morainic lakes are classified, according to the shape of their basins, into three divisions:

1. *"Kettle-hole" lakes* with round cauldron-shaped basins—usually of great depth. The size of the basins varies much, Bull's Eye Lake, two miles north of Valparaiso, Porter County, having an area of but one-half acre, with water 45 feet in depth, while Gage Lake, Steuben County, is one mile long by three-quarters of a mile in diameter, with a maximum depth of 70 feet. Other notable examples of the kettle-hole form, described in detail on subsequent pages, are Blue River Lake, Whitley County; Clear Lake, Steuben County and Pretty Lake, Lagrange County.

The origin or mode of formation of the kettle holes in which these lakes occur was for a long time a puzzle to geologists, but the study of existing glaciers has revealed the process. During the retreat of the glacier from the region where the kettle holes occur a great mass of ice was embedded in the debris where each kettle hole now exists. By its melting a cavity was left the shape and size of which depended upon the shape and size of the ice block and the amount of drift originally covering it. If the bottom and sides of the resulting kettle hole were of a porous nature it remained dry; but if they were of a stiff, impervious clay it in time became filled with water up to the level of the lowest point in its rim. If so located

that the annual rain fall exceeded the evaporation, it became possessed of an outlet. Many examples of kettle-hole lakes without visible inlet or outlet are known. Among these, Walden Pond, near Concord, Massachusetts, made famous by the writings of Thoreau and Emerson, is perhaps most notable. There is usually drainage enough from the region around its basin to balance the loss by evaporation.

2. *Channel lakes,* or those with long narrow basins whose bottoms are very uneven, the water in places forming deep pools, in others being shallow. One of the best examples of such a lake in Indiana is Tippecanoe Lake, Kosciusko County, its basin being five miles long and in most places less than one-half mile wide. The irregularity of its bottom is shown by the variable depth of its waters, one of its pools being 121 feet deep, which is the greatest depth found in any Indiana lake. Other noteworthy examples are the long, shallow arm of Crooked Lake, Steuben County; also Long Lake, Lagrange County, and Shriner and Cedar lakes, Whitley County. All of these were formed by the erosion of the great streams which flowed from the retreating and melting glaciers. The morainic material dropped by the glacier was soft and loose, and the mighty stream rushing forth from the base of the melting ice ploughed its way through this with little opposition. As a result a broad and deep channel was left, whose mouth or lower end was afterward partially filled by sediment, thus damming back the water and forming the lake of to-day. A stream, variable in size, usually forms the outlet of these channel lakes and often connects several of them which occupy the same valley, thus forming a chain. For example, the Tippecanoe River flows through the lake of that name, above mentioned, and connects its three basins, James, Tippecanoe and Oswego, so that they practically form one body of water.

3. *"Irregular lakes,"* whose basins are very complex in outline, being branched, lobed and otherwise irregular. The bottom is also very uneven, deep pools of water alternating with shallow areas, without regard to order or regularity. The majority of the lakes in Indiana belong to this class, Lake Maxinkuckee, Lake Wawasee, Bass Lake and Lake James, Steuben County, being the largest and best examples. Each of these lakes was doubtless largely formed by the irregular heaping up of the drift about the area now included in its basin, leaving this the lowest land in the vicinity. The bottom and sides of this low area happened also to be composed of an impervious clay or other material into which the water did not sink. Many low basins were left by the retreating glacier which might

have become lakes had their bottoms not been of sand, gravel or other porous debris, which would not hold water. There is little doubt but that many of the lakes, bays, channels, etc., auxiliary to the main basins of the lakes of this group, were formed by erosion and other agencies at the time the surrounding drift was being dropped where it now rests.

A lake of small size, like those in Indiana, begins to die the moment it is born. In other words, its basin begins to fill with material other than water, and the process of final extinction is commenced. There are more beds of extinct lakes in northern Indiana to-day than there are existing ones. Their former basins are now the sites of extensive bogs or meadows underlain by 15 to 20 feet of muck and marl. All of the lakes now there are in various stages of existence or extinction.

The agencies which bring about the extinction of lakes are several in number. One is the *carrying in of debris or foreign matter by streams and springs.* The majority of the lakes are fed by great springs which well up from the bottom and so replace the water lost by evaporation. In the early history of the lakes the water brought in by these springs was so strongly charged with salts of lime that the resulting deposits of marl did far more to fill up the lake basins than any debris of surface erosion brought in by the streams. Those lakes which at present are fed mainly by streams are becoming shallow more rapidly than those fed by subaqueous springs, as the streams are much smaller than they were a score of years ago, and are each year lessening in size. The amount of debris annually carried into the lakes by streams and springs is very much less now than when the lakes were young. Then the surrounding material left by the glacier was not bound down and held in place by the roots of trees and other vegetation but was loose and readily eroded. The carbonate of lime and other materials in the surrounding high lands was then soft and easily soluble. It is probable that four-fifths of the marl now existing on the bottoms of the lakes was deposited there during the first half of their existence.

The *artificial drainage* carried on by man is a second important cause of the extinction of Indiana lakes. In order to reclaim a few hundred acres of adjacent marsh land a dredged ditch is put through it, which either taps the lake itself or allows its waters to slowly seep away; or it may be that the ditch drains the principal water supply of the lake and so causes the latter to lose by evaporation much more than it receives from without. Bruce Lake, Fulton County; High and Bear lakes, Noble County, and Loon Lake, Whit-

ley County, are notable examples of former magnificent bodies of water, but now mere mud holes, and made so by the avaricious greed of man for more tillable land. Many others have lost half or more of their former water area by the same cause.

The *decrease of water supply* in the vicinity of lakes is another reason for their rapid extinction. This supply comes in the main, if not wholly, from the rainfall of the season which, soaking into the earth, finds its way through springs into the basins of the lakes, or is carried more immediately thereto by surface streams. The settlement of the regions about the lakes caused most of the timber to be cut away, and the land to become so drained that the water flows rapidly away instead of, as formerly, soaking into the ground and slowly seeping its way into underground currents, which finally emerged as springs about the rim of the lake or welled up from its bottom. For example, the outlet of Fish Lake, Steuben County, "was gauged in August, 1830, when its discharge was found to be much greater than in the year preceding and amounted to 18.64 cubic feet per second while the discharge into it on the same day from three small spring branches amounted to only 4.94 cubic feet per second. The supply, therefore, accruing from subterraneous sources was 13.70 cubic feet."* At present, especially in those lakes which have an outlet, the surplus water of a heavy rainfall is carried away at once, and the after seepage is often not sufficient to replace the loss by evaporation.

The most important cause of the extinction of lakes is, however, *the replacement of their water area by muck, formed by the decay of aquatic vegetation.* These muck beds are usually found upon the west and south shores of the main basins of the lakes, the east and north shores having their margins either of sand or mud, a condition due to the prevailing westerly and southerly winds, which create a stronger and more continuous breaking of the waves along the eastern and northern shores and so prevent the formation of muck. The bays and narrow channels are also more apt to be choked by vegetation and become filled with muck, on account of the limited extent to which their waters are exposed to wave action. In the words of Dr. Dryer, "the lakes are literally being filled with solidified air, the great bulk of the solid material which composes the plants being absorbed from the gaseous ocean above and consigned to the watery depths below."†

* Report of Howard Stansbury, U. S. Engineer, on the "Michigan and Wabash Canal," 1835, p. 15.

† Studies in Indiana Geography, p. 60.

A lake which has been raised by damming its outlet is more apt to have mucky margins than one which has been lowered, as the aquatic plants take root easily in the soil which lies beneath the newly acquired water area. Where muck meadows—former portions of the water area--border a lake the transition from the species of vegetation covering their surface to those growing in the water on the outer edge of the muck beds is a gradual one. In the water eight to 12 feet in depth, are pondweeds (*Potamogeton*), water shield (*Brasenia*), bladderwort (*Utricularia*), and water-millfoil (*Myriophyllum*). As the water decreases in depth, first the white water lilies (*Castalia*) and then the spatterdock or yellow water lily (*Nymphæa*), appear. With the latter are usually pickerel weed (*Pontederia*) and often the green arrow-arum (*Peltandra*). A little higher up and growing in the muck which reaches to or nearly to the surface of the water is usually a thick bed of cat-tails (*Typha*) and arrow-head (*Sagittaria*), while farther back are the sedges and grasses of a typical muck meadow. The most of the muck in the water is formed by the decay of the water lilies, especially the spatterdock, whose roots, stems and leaves are large and thick. The muck reaching nearly to the surface of the water is each season crowded still higher by the action of the ice, while the cat-tails, etc., growing upon it soon bring it wholly above the surface to form a part of the already existing meadow.

The water area of every lake in Indiana is thus being encroached upon by muck, some slowly and along only a small portion of their margins, others more rapidly and around most of their shores. The process is, however, slow if measured by the years of a man's life; the muck beds extending into the lake often only a few feet in a century. One of the best examples of the almost complete extinction of a lake by the decay of plants is that of Clear Lake, St. Joseph County, which, from a large, clear body of water, has been reduced to a mere accumulation of beds of muck, surrounding a pool of deep water. Another example is that of Cedar Lake, Steuben County, the former site of which—a square mile or more in area—is now a muck meadow. The water area of those lakes which have their bottoms mainly of marl or sand is much less subject to the encroachment of muck beds, since the aquatic plants growing therein are few in number and stunted in size. In the lakes with sand bottom the species of rushes (*Scirpus*) are often the only aquatic plants of note, while in several lakes whose bottom is composed wholly of marl, as Lime and Silver lakes, Steuben County, no vegetation at all is visible.

Like the lengths of the caves of southern Indiana, the depths of the northern Indiana lakes are greatly exaggerated by the surrounding inhabitants. According to their story, many of them "are bottomless" or have deep holes in which it is "impossible to find the bottom." Their attempts at sounding were probably made with an ordinary fishing line or the butt end of a cane pole. Mr. Stansbury, at the time of his survey in 1830, evidently took stock in the local stories regarding the depths of the lakes, as is shown by the following extract from his report above cited:* "The country around the summit level in Steuben County abounds in small lakes, from a half to two miles in length, either connected together in chains, or separate and alone, without any apparent inlet or outlet. They consist of the purest spring water, are full of the finest fish, and are of immense depth; in one of them, the bottom, as I have been informed, was sought in vain with a *line of 250 yards*." No one of the local residents who has such beliefs concerning the bottomless pools has ever brought up a Chinaman's queue on his fish hook, or a new species of fish from the central regions of the earth. In fact, the deepest water found in any lake in the State, and all of them have been carefully sounded, is 121 feet, in Tippecanoe Lake, Kosciusko County. Two or three others have water above 100 feet in depth, but in most of them the deepest pools are less than 70 feet. The following is the area and greatest depth of the five largest lakes in the State:

	Area in Square Miles.	*Maximum Depth.*
Lake Wawasee or Turkey Lake, Kosciusko County	5.66	68 feet.
Lake Maxinkuckee, Marshall County	2.97	89 feet.
Lake James, Steuben County	2.62	87 feet.
Bass Lake, Starke County	2.23	32 feet.
Tippecanoe Lake, Kosciusko County	1.61	121 feet.

In conclusion it may be said that all of the morainic lakes in Indiana are "geologically young, being confined to the very latest moraines of the glacial period. They are mere babes born yesterday and destined to die to-morrow. The present dominant race of men may pass away and leave these lakes still lying like bright jewels among the hills; but every one is doomed to final extinction.

'The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go.'

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* Page 14.

"But of all the features of the landscape, lakes are the most ephemeral. As long as they remain they will continue to contribute to the service and delight of man, by affording means for that relaxation and healthful pleasure which the conditions of modern life demand."*

MARL.

As stated in the paper on the Portland cement industry, the ingredients used in making that cement are some form of lime-carbonate and clay. In the majority of Portland cement works in the United States limestone is the form of lime-carbonate used. This must be crushed and ground fine before being utilized. In the Portland cement works now in operation in Ohio, Michigan and Indiana, *marl* is used as the carbonate of lime ingredient. With marl the expense of crushing and grinding the raw material is in part saved, and with care in choosing and mixing the marl and clay a good cement can be manufactured more cheaply than with limestone.

Definition and Properties.—Marl, or "merl," as it is commonly called in the country, is a soft, earthy material, composed principally of an amorphous form of carbonate of lime. Its color varies with the percentage of impurities which it contains. In the wet or damp state in which it occurs in lakes or marshes, it ranges from a milky-white through varying shades of brownish-yellow to a dark brown, which may finally grade over or merge into the overlying or adjacent muck. After exposure to the air a short time a wet marl that at first may seem almost white turns a bluish or drab color, on account of some chemical change which takes place. In drying the color of the marl tends to lighten again, but seldom gets beyond a light dove color, and is generally a decided drab, running from a light drab to a slate color. The purer forms, however, when dry, are white or slightly cream colored. The grains or particles composing the dry mass cohere very loosely and vary in size from coarsely granular to fine powder. They effervesce very freely and in time wholly disappear when a few drops of muriatic acid are applied, and in this way may be readily distinguished from any soft clay or mud, which effervesces or bubbles but slightly or not at all upon the application of acid. On dissolving the marl in acids small particles of vegetable and other organic and insoluble materials usually remain scattered throughout the solution.

* Dryer, Studies in Indiana Geography, 1897, p. 59.

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ILLUSTRATING MARSH DEPOSITS OF MARL.

(a) Deposit at Goose Lake, near Fish Lake, Laporte County, showing white marl surface, scant vegetation (bulrushes), and cracking due to drying. The footprints and bicycle track show the soft character of the deposit.

(b) Distant view of Silver Lake, Steuben County, showing an encroachment of marsh conditions on lake due to filling up with marl.

OCCURRENCE IN INDIANA.—Deposits of marl of sufficient size to justify the erection of cement factories occur in Indiana only in the three northern tiers of counties. Small deposits are found scattered here and there in other portions of the drift-covered area of the State, but none have been reported south of this glacial area. The reason for this is obvious and will be noted when we deal with the origin of the marl.

Except in a few instances where small deposits occur on hillsides, where they have been formed by the seeping waters of springs, all the beds of marl in Indiana are found either in existing or extinct lakes. Many of the deposits are found in marshes, now partly or wholly dry, but easily recognized as former lakes or ponds.

In hardness and consistency the marl as it occurs in lakes resembles somewhat soft butter. In some of the marsh deposits outside of the lakes it is firm enough to be cut out in blocks and handled with a shovel, but not easily because of its tendency to stick to the shovel. When piled up it tends to settle and spread slightly, though not usually to such an extent that it runs down to a level surface. Much of that found about the margins of lakes has the consistency of common mortar when ready for use. From the semi-solid condition found in marshes, it runs to the other extreme, where it becomes more like a thin pudding or thick soup. Some of the water deposits seem, in fact, to be only undergoing the process of deposition. From a boat it appears in such cases as though the water were only a few inches deep. But a very slight movement of the water is sufficient to either set the apparent bottom in wave-like motion, or to stir it up into a white cloud-like mass, which rises to the surface of the water. If allowed, however, it will quickly settle back to its old condition. An iron bar will sink rapidly of its own weight in such marl. In such a deposit it would seem as though the marl did not occupy over one-fourth of the space, the rest being water.

Usually the marl in the lakes forms a distinct body from the water, appearing like an ordinary lake bottom, except for its being whiter. An attempt to wade out into the water, however, at once shows the difference, for generally one sinks two or three feet at every step, and an oar put down from a boat is easily pushed its whole length into the marl, provided the latter is of sufficient depth. Where it is above water or at the surface in the marshes the marl can usually be crossed on foot, one not, as a rule, sinking more than six inches into it, and sometimes hardly at all, particularly if there has been some vegetation growing on it. In these places it is often quite difficult to force the iron rod its full length, 16 or more feet, into it,

or withdraw it after being so forced in. Where the marl in a marsh is covered with muck or peat, its upper surface is level and wholly distinct from the lower surface of the overlying muck or peat. The marl, in other words, appears as a distinct stratum and does not merge irregularly into the overlying mass. When exposed, this marsh marl is usually whiter in color than that in lakes, though chemical analyses do not show it to be of greater purity. Like the more recent water deposits it has usually remains of shells scattered through it, the most common form being the fresh water univalve—*Helisoma trivolvis* Say. Where both muck and peat overlie the marsh marl, the peat lies next to the marl, the muck forming the surface layer. Sand or gravel underlies most of the marl deposits in Indiana, though in a few instances the rod struck a tough blue clay after passing through the bed of marl.

In size the marl deposits of Indiana run from a fraction of an acre to several hundred or a thousand or more acres. Lake Wawasee, including the arm known as Syracuse Lake, contains about 1,700 acres. Several deposits run over 800 acres, though in some cases this is not all commercially available. Areas of 100 to 200 acres are still more numerous, though the majority of the deposits run under 100 acres. This may be an under-estimate based largely on the fact that a large majority of the deposits examined showed less than 100 acres of shallow water marl or commercially available marl.

The thickness of the marl beds in Indiana varies from 0 to 45+ feet, a deposit of the latter thickness having been found in Turkey Lake, Lagrange County. Many deposits are everywhere less than 10 feet in thickness, but the majority exceed 16 feet in places and often over the major part of their areas. As 16 to 20 feet was the total length of the rod used on the lakes, the actual or maximum depth of the marl beds was often left unknown. Experience has shown that a testing rod 16 or 18 feet in length is as long as one man can readily handle in an open boat. Where greater lengths are used a platform is usually built over two boats and this being securely anchored, two or more men can make the tests. By such means, according to the map furnished of tests on Syracuse Lake, Kosciusko County, depths of 60 feet were reached with a maximum thickness of marl of 40 feet and bottom not reached. Depths of 25 to 30 feet or over were reported at several places. From our own experience it seems safe to say that a large majority of the deposits have a maximum depth of over 20 feet, even though the area of the deposit be quite limited.

ORIGIN AND DEPOSITION OF MARL.—The deposition of marl in the still water of lakes and ponds is, as yet, not fully understood by scientists. Several theories have been advanced, no one of which seems to fully account for the deposits as they actually occur. Since the remains of several existing species of shells are found in abundance in almost all of the marl beds, it was at first thought that the marl itself was derived from the remains of such shells. Such is at present the belief of most people who have made only a superficial examination of the marl deposits. An extended investigation soon shows that the immense size and thickness of the deposits precludes their origin from the remains of shells. A small portion of the marl is doubtless formed from the shells since these mollusca exist in numbers in all bodies of fresh water. Moreover, the shells are composed mainly of carbonate of lime, the same as is the marl. But the number of shells imbedded in the marl is not greater than would naturally exist in the waters of the lake at the time the marl was being deposited. As they died the majority of them were covered with the marl and were by it kept from being ground into fine powder by wave action. Some of them were doubtless so ground and their remains went to swell the bulk of the marl, but not more than one per cent. of the latter is, in our opinion, so derived. When the marl is exposed, numerous nearly entire fragile shells are found embedded in its mass. Should the marl beds, in the course of ages, become hardened into stone, such shells might become "fossils," and bear the same relation to the marl-stone as other fossils bear to the beds of limestone in which they occur. It is, of course, preposterous to think that any bed of limestone is wholly formed from the crushed remains of the same species of shells as those which have become fossilized in its midst, however abundant the latter may be. The same is true of the deposits of marl.

Since the marl occurs only in the drift-covered area of Indiana, and the larger beds are found in the vicinity of the thicker deposits of drift, there is evidently a close relation between the marl and the surrounding drift. A careful study of the marl leads to the belief that this relation is two-fold in nature. *First*, the lakes and ponds in which the marl is being and has been deposited occupy depressions formed by the irregular deposition of the drift. *Second*, the immediate source of the marl is the glacial clays which form so large a component part of the surrounding drift. These clays were transported to and deposited where they now lie by a great glacier or moving sea of ice which, thousands of years ago, was formed in the regions to the east and south of Hudson's Bay. The climate

of those regions was, for a long period, similar to that of Greenland to-day, or even colder. The snow, ever falling, never melting, accumulated during hundreds of centuries in one vast field of enormous thickness. Near the bottom of this mass a plastic, porous sort of ice was gradually formed from the snow by the pressure from above. This ice mass or glacier took upon itself a slow, almost imperceptible, motion to the south and southwestward. As it moved thus onward great masses of partly decayed rock and clay from hillsides and jutting cliffs rolled down upon it and were carried on and on until, by the melting of their icy steed, they were dropped hundreds of miles from the parent ledge. Large, irregular masses of rock from the region in which the glacier was formed were either frozen into its nether portion or rolled along beneath it, and as the ice sheet moved they served as great stone drags, grinding down and smoothing off the hills and ridges and filling up the valleys, until the irregular, uneven surface of the old preglacial rocks was planed and polished. In this way all the beds of so-called "drift clays" were accumulated where they lie.

Transported and deposited as they were, it is no wonder that the majority of the drift clays are too impure for any use but the making of ordinary brick and drain tile, and oftentimes they contain too much lime even for this purpose, numerous analyses showing the presence of as high as 40 per cent. of calcareous material. This is due to the grinding up and mixing with the clays much of the soft surface limestones over which the glacier passed, as the erosion of that epoch not only removed and commingled the previously formed residual deposits, but planed away the country over a vast area to a greater depth than had been reached by any previous decay. These eroded limestones and the clays with which they were mixed were many of them ground into impalpable powder, and deposited as rock flour in the places where they now lie. They are rich, therefore, in finely divided limestone and other soft rock-forming minerals, many of which contain the components of marl.

Vast deposits of these glacial clays compose the hills and higher ground surrounding the lakes. Upon these deposits the rain of centuries has fallen, gathering unto itself before it reached the earth a part of the gaseous carbon di-oxide of the air. Rain water containing carbon di-oxide is a weak form of carbonic acid ($H_2O+CO_2=H_2CO_3$). This weak acid or acidulated water, wherever it comes in contact with limestone dissolves and holds in solution, up to a certain point, the carbonate of lime; the result being calcium bi-carbonate according to the following formula: $H_2CO_3+CaCO_3=$

$CaH_2(CO_3)_2$. Percolating through the deposits of glacial clays and limestone debris the rain water dissolves and becomes saturated with the carbonate of lime. It then flows onward underground until it issues forth in the form of a spring, either bubbling up from the bottom of the lake or flowing in from the side.

This spring water as it enters the lake is always colder than the waters of the lake itself. The bi-carbonate of lime is more soluble in cold water than in warm and a *part* of the dissolved material is therefore precipitated in the form of a fine powder soon after the cold stream enters the warmer, still water of the lake. Such precipitation of calcium carbonate from cold water as it becomes warm is seen every day in almost every household. The hard water heated in tea-kettles holds, while cold, a large quantity of bi-carbonate of lime in solution. As it becomes warm much, if not all of this, falls and forms a coating of lime upon the bottom of the kettle.

Again, if there is a large amount of carbon di-oxide in the percolating water, the percentage of carbonate of lime held in solution will be increased in proportion. As the spring water enters the lake and rises to the surface the pressure will be decreased and a part of the carbon di-oxide will escape, and so cause a precipitation of *another part* of the bi-carbonate of lime according to the following formula: $CaH_2(CO_3)_2—CO_2=CaCO_3+H_2O$.

Most if not all of the marl lakes examined in Indiana are fed by these subterranean or sub-aqueous springs, even though they have streams entering and leaving them. The larger deposits of marl in the lakes are found in close proximity to these springs and not along the direction of the current of water entering by inlet or leaving by outlet. In fact almost every lake which has a stream entering it has a large area of its bottom adjacent to the inlet covered with muck and silt from which much aquatic vegetation springs. A part of this muck and the most of the silt is brought in by the entering current, especially if the latter be in any way rapid. Where the inlet is sluggish and runs through a marshy area, more or less marl is often found along its bottom, quite a distance back from the lake. These facts do not bear out the following statement of a recent writer on the subject: "Theoretically, then, some, if not a great part of the dissolved matter, should be thrown down along the courses of the streams which connect the original outlets of the water from calcareous clays and lakes where marl occurs, and we should find the marl occurring in small deposits along these streams wherever there is slack water. Moreover, we should expect the waters of these springs and streams to show more or less milkiness on standing

exposed to the normal pressure of the atmosphere at usual temperatures. Actually, however, none of these phenomena have been noted, and we infer that there is not a large amount of carbon dioxide, and not an approach to the saturation point for the calcium bi-carbonate, in the springs and streams feeding marly lakes."*

Mr. Davis evidently does not take into account the fact that most of the marl enters the lakes by means of hidden springs and not by the streams or inlets flowing above ground. The waters of the latter are mainly surface waters which are gathered from over a wide area. They have not percolated to any great extent deep beds of glacial clays and therefore, even if the amount of carbon di-oxide were great when the water fell upon the surface, the amount of carbonate of lime or marl material held in solution is small. Moreover, flowing as they do exposed to the air for long distances the carbon di-oxide will in great measure have escaped before the waters of the surface streams enter the lakes. Again, the amount of carbonate of lime held in solution by water, even where the latter is saturated with carbon di-oxide, is too small to show appreciable milkiness when standing. According to T. Sterry Hunt, water so saturated will not hold more than one part in one thousand of the carbonate of lime, and pure water only one part in thirty to fifty thousand.† For this reason the process of deposition of the marl in the lakes is necessarily a very slow one. It has been going on for hundreds of centuries, for the lakes and their surrounding beds of glacial debris have been in existence since the close of the glacial period. It was probably much more rapid in the past than at the present for the more soluble materials composing the glacial clays were doubtless first removed by the filtering waters. That the deposition is still going on is shown by the fact that many of the living organisms of the lakes, as shells and aquatic plants, are coated with the marl. All facts go to show that the beds of marl have been formed in much the same manner as have many of the beds of fine-grained limestone of paleozoic age. They are both sedimentary deposits, the principal difference being that the limestones are composed mainly of the remains of minute organisms which slowly fell in great masses to the bottom of the sea water, and were afterward covered with a different sediment and hardened by pressure and other forces. Given thousands of years and similar conditions, and the marl would also be changed into a somewhat similar limestone.

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*Chas. A. Davis, "The Natural History of Marl," Journal of Geology, VIII, 1900, p. 486.

†Chem. and Geol. Essays, p. 139.

Another factor which reduces the amount of carbon di-oxide in the entering waters and therefore causes a farther deposition of the marl, is undoubtedly the aquatic plants which grow in many of the marl-bearing lakes. Any one who studies the botany of such a lake soon notes that the stems of many of the submerged plants are encrusted with mineral matter, which, when removed and subjected to acids is easily shown to be carbonate of lime. "It is also easy for a casual observer to see that the deposit is not a true secretion of the plant, for it is purely external, and is easily rubbed off the outside of the plants in flakes, while the tissues beneath show no injury from being deprived of it, and again, the same species of plants in some sections of the country do not have any mineral matter upon them. The deposit is formed incidently by chemical precipitation upon the surface of the plants, probably only upon the green parts, and in performance of normal and usual processes of the plant organism.

All green plants, whether aquatic or terrestrial, take in the gas, carbon di-oxide, through their leaves and stems, and build the carbon atoms and part of the oxygen atoms of which the gas is composed into the new compounds of their own tissues, in the process releasing the remainder of the oxygen atoms." When the carbon di-oxide is removed from the surrounding water by the aquatic plants the carbonate of lime, held in solution on account of the presence of the gas, is precipitated. A part falls upon and encrusts the leaves and stems of the plants. Another part falls to the bottom and increases the thickness of the marl bed in which the plants have grown. When the plants die, their encrustation, as well as the organic matter in their bodies, is also added to the marl deposit.

The principal plants which thus aid in the deposition of marl in Indiana lakes are the different species of Stoneworts or Chara. They are easily recognized by "their jointed stems, which have at each joint a whorl of radiating branches, which are also jointed. In some species the stems and branches are covered with a thick coating of mineral matter, are almost white, and very brittle because of this covering. These plants not only grow near the surface of shallow water, where it is unoccupied by other plants, but in the deeper parts as well of our ponds and lakes, and, as they thrive where the light is feeble, they continue to grow throughout the year, although in winter they must grow less rapidly than in summer, because ice and snow on the surface of the lakes make less favorable light conditions."*

* Davis, *loc. cit.*, p. 491.

However, not more than one-half of the marl lakes of this State possess the beds of Stonewort in any abundance. Again, the species of Chara are often found in lakes which contain no marl or in those portions of marl-bearing lakes remote from the marl itself. Where present in large quantity the stems of these plants, as they die and decay, add much organic matter to the marl and so cause it to be inferior in quality. In fact, all marl deposits covered with Chara are darker in color and show a smaller amount of carbonate of lime when analyzed than do those devoid of plant life. Some of the larger and thicker deposits of the whitest and purest marl in the State are found in Lime and James Lakes, Steuben County, and Tippecanoe and Dewart Lakes, Kosciusko County, where Chara and other plants are almost wholly absent, thus showing that the presence of plant life is not necessary to the deposition of the marl.

Another group of plants which evidently aid in the depositing of the marl are some of the lower forms of Algae. The cells of these are found in great numbers intermingled with the particles of marl in the encrustation on shells and in the concretions and pebbles of carbonate of lime found in James and neighboring lakes, Steuben County, and in Milford Lake, Kosciusko County.

SUMMARY.—From the foregoing statements we therefore conclude:

First.—That the marl deposits of Indiana have been formed in the still waters of lakes now in existence, or in former lakes, now extinct.

Second.—That the original source of the marl material is the glacial clay in the region surrounding the lakes.

Third.—That the deposition of the marl is caused by the loss of carbon di-oxide from the sub-aqueous spring waters which bear the marl material into the lakes.

Fourth.—That this loss of carbon di-oxide is, for the most part, caused in three ways, viz.:

(a) By the increase in temperature of the incoming spring water.
(b) By the decrease in pressure as the spring water rises to the surface of the lake.
(c) By the action of different aquatic plants in abstracting the carbon di-oxide for food.

RELATION OF MARL TO DEPTH OF WATER.—One of the most striking facts brought out in a detailed study of the marl deposits is the great irregularity in their occurrence. One part of a lake or marsh may contain a bed of marl 16 feet or more in thickness while in another part, 10 to 20 rods distant, it may be wholly lacking. This

irregularity is doubtless largely due to the presence or absence of sub-aqueous springs. If they are absent in a lake and the latter is fed only by surface streams, there will be little or no marl found in its bed. One part of a lake may have a number of these springs welling up from the bottom or flowing in so as to enter the lake bed where the water is six feet or more in depth, and in other portions of the same lake they may be wholly absent. Under such conditions, if the lake be a large one, only that portion of its bed adjacent to the springs will likely be covered with marl. If it be small, the whole bottom may be covered, but the thickness of the deposit will be variable.

In the earlier Geological Reports of Indiana, the marl, when mentioned, was usually described as "composing the shore," or "bordering the lakes," or as "occurring around their margins," thus giving the impression that it was confined to the shallow-water area of the lake, or occurred only between the limits of high and low water. Recent tests, however, have shown marl to occur at probably all depths of water, and with often greater thickness of marl in deep water than in shallow. No data were obtained concerning the character of the bottom at depths of 100 feet or over. Perhaps the greatest depth at which we have data of the occurrence of marl is in Turkey or Wawasee Lake, Kosciusko County, where, in the plankton survey carried on by Mr. Chancey Juday, marl was found under all the deeper water up to 69 feet, the deepest point in the lake. Interpreting this in the light of our knowledge of shallower lakes it leads us to the conclusion that, as a rule, the marl occurs abundantly in the deeper water of all the lakes where it occurs at all. In a few of the lakes this rule did not appear to apply, for the marl found close to shore appeared to thin out in 10 to 15 feet of water. This was probably due to the fact that but few sub-aqueous springs entered such lakes and they only along the sides in the shallow water. It is possible a similar thinning out takes place in many other instances at depths too great for the fact to be observed with the facilities at our command. But in general the data seem to indicate not only a deepening of the marl toward deeper water but a more wide-spread distribution. Thus in many lakes the distribution of the marl close to shore is irregular so that perhaps not more than half of the three-foot water has marl under it, but in nearly every such case it was found that the eight or ten-foot water is almost all underlain with a thick deposit of marl. At present this deep water marl is considered unavailable for manufacturing cement, but there can be but little question that, as need arises, means will

be devised for securing it with at least fair economy. It should be therefore taken into account in any calculation of the quantity of marl in a deposit.

In some cases the accumulation of marl has almost or quite filled up the lake. This is notably true in what are now marshes. In such cases it is evident that the marl is thickest at the points where the water was deepest when the marl began to deposit. In small lakes which have been recently drained, it is also found that the thickest beds of marl underlie those portions of the former lake over which the deepest water occurred.*

In any case it is evident that the thickness of the marl is limited by the depth of the sub-marl surface below the water surface. For this reason, even though accumulation is most rapid in the shallow water, the water surface, and hence the limit of accumulation, is more quickly reached, so that the slower accumulations in deeper water may continue until many times as thick as those in shallow water. In those cases where a lake becomes entirely filled up, the thickness of the marl at every point will be equal to the original depth of the water at every point, except as modified by changes in the water level. These conditions are frequently met with close to shore in unfilled lakes. Here, however, on account of wave action the surface of the marl seldom reaches the surface of the water except just at the shore line.

Marl islands, reaching almost or quite to the surface of the water, are often found in the deeper parts of the lakes. Sometimes there is a visible connection of marl under water, between these islands and the nearest shore. Again they are quite isolated from other beds of marl. In either case they are probably above and surrounding the orifice of a former, large sub-aqueous spring which bubbled up from the bottom of the lake.

Where the bed or basin of the lake is narrow and deep, it is manifest that the majority of the springs feeding it must enter from the sides. In such cases the larger and thicker deposits of marl naturally occur around the margin and it is probable that much of the marl after deposition is gradually carried down to fill up the deeper parts of the lake.

While complete detailed drillings of a number of the deposits would be desirable, we are fortunate in having one, that of Syracuse Lake, Kosciusko County. One of the most notable things shown by the detailed drilling in this lake is the tendency

*See detailed descriptions of deposits at Houghton Lake, Marshall County; Shallow Lake, Steuben County, etc.

towards filling up the hollows of the sub-marl surface. In several cases this has progressed until deep hollows have been filled up even with the marl over the higher ground on either side, so that no hint of the greater depth of the marl is given by the present depth of the water. From this we deduce that the deepest marl is probably found in places where the water was deepest when the marl began to be deposited; also that the present depth of the water may or may not be an indication of the greater or less depth of the marl. Where the lake had originally a uniform basin-shaped bottom it would generally be true that the deeper the water to-day the deeper the marl. But the bottom of most of the lakes examined was very irregular in shape, hence some of the deepest original depressions may have been so completely filled as to be in no wise indicated by the present depth of the water.

Finally it may be stated that the facts gathered go to show that most of the larger lakes, possessing extensive deposits of marl are slowly filling up the lowest depressions, thus making the bottoms of the lakes more and more level. Should this process continue indefinitely it could but result in these lakes being filled level full, just as many of the smaller lakes of the State have been filled heretofore.

Size of a Workable Deposit.—In the Portland cement industry, a cubic yard of marsh marl, of the consistency of soft putty, is used in making two barrels of cement. Where the marl is dredged from a lake, and contains much water, this proportion is necessarily greater. Careful estimates go to show that an acre of marl three feet in thickness will make 10,000 barrels of cement. From this data the length of time necessary to exhaust any deposit can be readily computed. At the present time a factory with an output of 500 barrels of cement each 24 hours, is considered of only medium size. As the process is a continuous one, with no stop for Sundays or holidays, such a factory will use a bed of marl nine acres in area and six feet in thickness each year.

The following table gives approximately the length of time which deposits of varying area and thickness will last a factory whose output is 500 barrels of cement daily:

Area in Acres.	*Thickness in Feet.*	*Barrels of Cement.*	*Time.*
1	3	10,000	20 days.
1	6	20,000	40 days.
1	12	40,000	80 days.
1	18	60,000	120 days.
9	6	180,000	1 year.
40	12	1,600,000	8.9 years.
120	12	4,800,000	26.5 years.
135	12	5,400,000	30 years.
160	10	5,333,000	29.6 years.
200	10	6,666,000	36.5 years.
90	18	5,400,000	30 years.
270	6	5,400,000	30 years.

Since a modern cement factory with a capacity of 500 barrels daily costs in the neighborhood of $350,000, the company erecting it wish a deposit of marl in sight which will last, at least, 30 years. From the table we note that a deposit equal to 160 acres, 10 feet in thickness, will last almost 30 years, and such a deposit will, in this report, be termed a "workable deposit." It is needless to say that the great majority of deposits examined were too small to be workable except on a very small scale. The time may come when by improved processes the amount of capital necessary to manufacture the cement will be materially decreased. Small factories may then be erected and the lesser deposits utilized. Again, there is no doubt but that appliances will ere long be perfected for securing the marl from beneath all water 20 to 60 feet in depth. The amount of available marl will then be greatly increased, and a number of deposits not now considered workable will then be utilized.

Uses of Marl.—The marls found in Indiana can be used for the following purposes:

First.—As an ingredient in the manufacture of Portland cement.

Second.—As a fertilizer of soils.

Third.—As a means of improving the mechanical condition of clayey, sandy or peaty soils.

Fourth.—As a mineral food for poultry, furnishing them the necessary ingredient for shells of eggs.

Fifth.—As a polishing powder.

Sixth.—As a material for the manufacture of quicklime.

Seventh.—In the place of limestone in the manufacture of beet sugar.

PLATE 7.

ILLUSTRATING USES OF PORTLAND CEMENT.

Highway Bridge, constructed of Portland Cement Concrete.

These possible uses will be taken up in the order mentioned and briefly discussed.

First.—Its use "*As an ingredient in the manufacture of Portland cement*" has been fully discussed on preceding pages. Many farmers who have only 20 to 60 acres of marl have written to this Department asking for directions for making Portland cement, intending to use their deposit for this purpose. It will be evident, from what has been said, that it will not be practicable to utilize such small deposits for the manufacture of cement.

Second.—"*As a Fertilizer of Soils.*" A fertilizer is any material which furnishes a necessary plant food to soils. It is well known that wheat or any cereal uses as food the following chemical elements, viz., carbon, hydrogen and oxygen, which are derived mainly from the air and water and which make up the greater bulk of the grain and stalk; and, in addition to these, nitrogen, sulphur, potash, soda, lime, magnesia, phosphoric acid, chlorine and silicon, which are important, yea absolutely necessary, constituents.

If any *one* of these is lacking in the soil, or is present in a form not available by the wheat roots, the plants will not flourish, and the soil will be worthless for wheat production. Such a soil may, in most cases, be made to produce a crop of grain by adding to it the constituent which is lacking, but if this can not be done except at a prohibitory cost, or one at which more fertile ground can be procured, the soil may be regarded as "worn out" or "barren."

Any compound containing in an available form the element or elements of plant food lacking in a soil, is a *fertilizer.* From the analyses of Indiana marls which will be given, it will be seen that their principal constituent is carbonate of lime. Other than it they contain but a small percentage of one or two of the important elements used as plant-foods. Their value as fertilizers, therefore, depends almost wholly upon their lime component. Lime is one of the elements used as food by most plants, and it is therefore necessary to supply some compound containing it in case it is not found in sufficient quantity in the soil.

According to the German scientist, Dr. Maercker, a lime content in a soil of one per cent. is always sufficient; where one-half to one per cent. of lime is present, the application of lime fertilizers is occasionally beneficial, and always so, when only one-quarter to one-half per cent. of lime is present. When less than one-quarter of one per cent. of lime is found in the soil, liming is absolutely necessary. Generally speaking, we may say that the content of lime can not fall much below one-half of one per cent. in a light soil, and one per cent. in a heavy soil, without impairing the fertility of the soil.

The great majority of Indiana soils are clayey, loamy or prairie soils, lying within the drift-covered area of the State, and, for the most part, containing a sufficient quantity of lime. The addition of marls to such soils would therefore be of little or no benefit. However, there are some large areas of light sandy soil in northern Indiana the fertility of which would undoubtedly be increased by a dressing of marl. Mucky soils, though usually containing a large percentage of lime, are often benefited by an application of marl or some other lime compound. The reason for this is that lime is present in these soils in combination with organic acids, as humates, ulmates, etc., which compounds can not supply plant food to crops until they are broken down and oxidized to inorganic materials. The effect of lime on marshy soils is partly in this direction, promoting the fermentation of vegetable matter and assisting in the decomposition of inert compounds so as to render them soluble in soil water and available as plant food, partly in the way of neutralizing free organic acids and of oxidizing poisonous iron compounds (ferrous salts) generally present in such soils.

An example of the beneficial results of marl on muck soil was noted on the land of F. M. Trissal, two miles northwest of North Judson, Starke County, in the summer of 1900. A field which a few years ago was part of an extensive marsh was being cultivated in corn. The surface was a loose black muck or semi-peat, two feet or more in thickness. Beneath this was a deposit of marl from two to six feet thick. In draining the field a ditch had been put down a foot or more into the marl and a quantity of the latter became mixed with the mucky soil when the ditch was refilled. On July 15th, the corn in three rows on either side of the ditch was fully twice the height of that in the remainder of the field, and it has since been learned that the yield of these rows was a third greater than that of the rows adjoining where the marl had not been mixed with the muck. Much of the mucky soil of northern Indiana is underlain with marl and the farmers owning such land could, at a small expense, bring about a mixture of the underlying marl and overlying muck. There is little doubt but that such a mixing would in the end prove highly remunerative. An account of the results of such mixing would, if properly compiled, also afford valuable data for those farmers and scientists who are interested in all important questions relating to commercial fertilizers.

Experience goes to show that good effects will follow the application of marls on land deficient in lime, but on account of the small amount of other plant food which they contain, their value is not

sufficient to justify shipment for long distances. The marl must therefore be used near where it is found and the price which it will command will be governed by the law of supply and demand. In the vicinity of much of the light sandy soil of northern Indiana there is an abundant supply of good marl, and the price in this region will therefore be very reasonable.

As to the application of marl as a fertilizer, we can not do better than to quote the following from a paper by Mr. F. W. Woll;* "Where there is a probability that beneficial results may be obtained by applying marl on a soil, it should be done directly before sowing or planting time, or as a top-dressing on clover or on grass land, provided the marl at hand is in the form of a dry fine powder; if it is wet and putty-like, and dries to large hard lumps, the dressing should take place in the fall or early winter so that the winter and spring weather, with alternating frosts and thaws, may gradually reduce it to a pulverulent mass. In countries where liming or marling is frequently done, special machinery is used for the purpose of distributing the material evenly over the land, which is of importance. It is very likely that our common manure spreaders will do the work in a satisfactory manner.

"The crops most likely to be benefited by applications of marl are the legumes (clover, peas, beans), grass, potatoes, corn, and root crops. As in case of other fertilizers, a small quantity of marl placed in the row or the hill will go farther and give better results for crops planted or sown in this manner, than the same quantity scattered broadcast.

"Like all lime compounds, marl has a tendency to exhaust the soil if applied excessively and for a series of years, as it renders valuable fertilizing ingredients soluble and therefore subject to leakage. The old European saying that 'lime without manure, makes the father rich and the son poor,' is an expression of this fact. Unless we start with a soil well supplied with fertilizing ingredients, aside from the lime added, the effects of dressings of lime or marl alone will therefore be of temporary benefit, but a detriment in the end. To avoid this difficulty, barnyard manure, or complete artificial fertilizers should be applied at times on marled or limed land. The liming or marling, if done thoroughly, need not be repeated on the same land oftener than every sixth to eighth year.

"Marl may furthermore be used to advantage for making composts with muck, barnyard manure, and refuse fertilizing materials; its action in this case depends on the favorable effect which it exerts

*"The Marls of Wisconsin" in Bull. 51, Wisc. Agr. Exp. Stat., 1896, p. 14.

on the progress of the nitrification of inert organic nitrogen substances. Where marl is near at hand and easily accessible, farmers should not fail to make use of it for this purpose, and also to apply it directly in varying quantities on small pieces of their land, so as to obtain definite knowledge of what it will do under their conditions.

"In some of the potato-growing counties of our State (Wisconsin) where land plaster is used extensively for mixing with paris green, shell marl in a fine powder has been advocated as a substitute for plaster. Marl of this character is well adapted to this purpose on account of its mechanical condition, but it can not be considered as valuable as plaster as a fertilizer owing to the fact that the latter, being a sulphate, is able to bind the free ammonia and carbonate of ammonia of the air and soil, thus preventing the nitrogen which they contain from going to waste. Land plaster is also in other respects of greater value to growing crops than is any form of carbonate of lime."

Third.—The use of marl *"As a means of improving the mechanical condition of soils"* is a very important one, and is worthy of more general practice than it has received from farmers in the past. A soil may contain all the elements or ingredients necessary for the production of a certain crop and yet, on account of its mechanical condition—its extreme looseness or porosity, or its compactness—plants can not grow in it. By the application of certain materials, one of the best of which is carbonate of lime, these unfavorable physical properties of the soil are often modified or broken up, so that the plants can avail themselves of the store of fertility in the soil, and a good crop is the result.

Many clay soils, when wet by rains, are not porous enough to allow the water to pass through them with sufficient rapidity. As a consequence they become water-logged and the air which is necessary for the healthy growth of the plant roots is excluded. In time of drought such soils cake readily, thus forming large clods, and becoming more difficult to till and less adapted to the sustenance of the growing plant. Marl or some other compound of lime, when applied in sufficient quantity, will prevent this puddling or caking, thus allowing the water, air and heat to thoroughly permeate the soil. The texture of the soil will also become more suitable for the easy penetration of the roots and rootlets of the plants.

If to a loose sandy soil a sufficient quantity of marl be added, the sand grains will in time become more or less cemented together,

thus lessening the large openings between the soil particles, and causing the better retention of heat and moisture.

Another way in which marl, or other compound of lime, improves the mechanical condition of soils is by its effect upon the action of microscopic organisms. "Many important changes are produced in the soil by organisms so small that they can only be observed by the aid of the most powerful microscopes. Some of the changes of this character in which lime plays an important part are the following:

"(1). The change of ammonia and of nitrogen in organic matter, such as blood, meat, fish, tankage, plants, etc., into nitrates, the form in which it is chiefly assimilated by most cultivated plants. This is known as the process of nitrification and is promoted by the presence of lime in soils.

"(2). The decomposition of organic matter in muck and other soils. In this process the production of carbonic acid is much accelerated by the use of lime. This carbonic acid in turn so acts upon the inert plant food of the soil as to make it more quickly available to plants. The indirect result, therefore, is to help the plant to draw more potash, phosphoric acid, etc., from the soil than would otherwise be possible.

"(3). The utilization of atmospheric nitrogen by certain of the leguminous plants (notably the clovers), particularly upon sour soils, is facilitated by the application of lime."*

Where marl is added to a soil for the purpose of furnishing the latter with lime for plant food, or as a fertilizer, the amount necessary will be much less than where it is applied to better the mechanical condition of the soil. In the former case a dressing of one to two tons per acre every six to eight years will generally prove sufficient. In the latter case as many as 25 to 40 tons per acre may be applied without harm. If the marl be spread out perfectly even over the surface a dressing of 40 tons per acre will form a layer about one-fourth of an inch thick.

Fourth.—"As a mineral food for poultry." Chemical analysis and experiments, together with reports from many practical poultry men, prove conclusively that the ordinary grain and green foods supplied to chickens and other fowls do not contain enough lime for the formation of egg shells. Several times as much lime as is ordinarily fed is necessary if good strong egg shells are to be produced. No form of lime is more convenient for this purpose than marl, its particles being in a state of fine division and easily assimilated as

* H. J. Wheeler, Farmers' Bull. No. 77, U. S. Dept. Agr., 1898, p. 6.

shell-forming material. Several farmers in the vicinity of marl deposits in northern Indiana have tried it, hauling up a load two or three times a year and placing it where the fowls had free access to it. They report that the chickens lay much better during the winter season. It is probably better to keep the marl thus continually before the fowls, trusting to them to eat the amount necessary to supply lime, than to mix it with their other food. The judgment of the fowl can be relied upon to secure the amount required. Poultry supply houses could doubtless build up a good trade for marl for this purpose were they to give the matter proper attention.

Fifth.—"As a polishing powder." Several different mineral products are used as "polishing powders," for scouring articles of silver, brass and other metals. Such a product, to be of value for this purpose, must be in a fine state of division and form an impalpable powder, free from grit or other similar impurities which might scratch the object to be polished. Beds of marl of this character, or which can readily be rendered suitable by grinding when dry, are of frequent occurrence in northern Indiana. On account of the limited demand for such powder it is not likely that the sale of marl for polishing purposes can ever become a source of much income to the owners of the deposits. The marl will, however, furnish an abundant supply of material for use in the kitchens of those homes adjacent to the beds.

Sixth.—"As a material for the manufacture of quicklime." In the early settlement of northern Indiana much quicklime was made from marl. No one of the counties in which the principal marl deposits occur, have outcrops of limestone, and hence the marl was used, being burned in rude kilns erected for the purpose. Richard Owen, in his report on St. Joseph County, says: "Beneath the swamp-muck beds in the Kankakee marshes near South Bend, a shell marl, three to ten feet thick, is obtained, in which are large and abundant specimens, some well preserved, of shells belonging to the genera ***physa, planorbis, cyclas*** and ***unio***. At many places this is dug and moulded into brick-shaped masses of considerable size, so as to be readily piled in a kiln, burnt and used for all purposes to which lime is usually applied, being an excellent quality and white color. An extensive manufacture of this kind is also carried on near the fine Catholic College of Notre Dame, beautifully situated a mile or two north of South Bend."*

Other localities where the marl lime was made, were near Rochester, Fulton County; Lime Lake, Steuben County; Albion, Noble

*Report of a Geological Reconnaissance of Indiana, 1859, p. 200.

County, and Silver Lake, Steuben County. The lime from the marl was snow-white in color, and very perishable owing to its fine mechanical condition. As much of the mortar made from the burned marl did not endure exposure to the weather (probably on account of too small an amount of sand being used in its composition) the use of marl as a lime material was discontinued when railways were constructed which brought in from Wabash, Delphi and Huntington a superior lime.

Since caustic lime or quicklime is the most concentrated form of lime which can be applied as a fertilizer, it might prove profitable to burn the marl into quicklime for that purpose. The manufacture of quicklime from the marl for use in mortar will, however, hardly be renewed, as the quality of the lime produced at the lime-burning cities along the Wabash, taken in connection with the present cheap and rapid means of transportation, will not justify its renewal.

Seventh.—The use of marl "*in the place of limestone in the manufacture of beet sugar*" has, as far as we can ascertain, not been practically tested, but we see no reason why the purer marls of northern Indiana could not be so used. From 2½ to 3 per cent. of lime is added to the juice of the beets as a purifying agent during the process of sugar manufacture. This lime is added to the juice after it has left the diffusion batteries and entered what are known as the carbonatation tanks. After the lime has been added carbonic acid gas is forced through the juice and the excess of lime is precipitated in the form of a carbonate, and carries down with it mechanically many of the impurities. This operation is terminated when the lime precipitate becomes granular and settles readily. At this point there still remains about a gram and a half of lime (CaO) per liter of juice. After having been passed through filter presses the juice is again treated while boiling hot, with ½ per cent. of lime, and carbonic acid is once more passed through it, until all the lime is precipitated. This second operation is termed the *saturation*, the former the first *carbonatation.*

In most beet sugar factories limestone is used, not only for the making of the lime mentioned above, but also in the making of the carbonic acid gas. Large areas of northwestern Indiana have, by practical tests, been proven in the highest degree suitable for the raising of sugar beets. An extensive factory will, in 1901, be erected at Shelby, Lake County, for making beet sugar, while several others will, in the next few years, doubtless be built in neighboring counties. Not an outcrop of limestone of sufficient purity occurs in or near any of the counties where these factories will be located, and such

stone will have to be shipped long distances. Since the better marls found in this region contain at least 92 per cent. of carbonate of lime, it would seem that they are pure enough to take the place of the limestone. Care would have to be taken in their selection, and they would have to be briquetted, but even then the cost would, we believe, be less than that of limestone. The experiment is at least worthy of consideration by parties interested in beet sugar manufacture.

METHOD OF MAKING SURVEY.—The survey of the marl area was made between September first and December first, 1899, by Dr. Ashley and at intervals during the spring and summer of 1900 by Mr. Blatchley. It was planned to be only a reconnaisance, made for the purpose of determining in a general way where the workable deposits lay. Such details as may be given were obtained incidentally to the necessary examinations.

The work in the fall of 1899 was almost wholly on the lakes from a boat. The testing was done with a drill composed of ¾-inch gas pipe, in lengths of three feet, screwed together at the ends. To the lower joint of pipe was attached a 1¼-inch carpenter's auger. The total length of the drill was 16 feet. The purpose of the auger was to open a passage for the rod; break up the marl so as to facilitate the withdrawal of rod and to bring up specimens of the marl for examination. When, therefore, in the detailed description, it says the marl is over 16 feet, or in two feet of water is over 14 feet, it implies simply that the rod did not reach the bottom of the marl at a depth of 16 feet from the surface. The marl at such a point extends downward at least to 16 feet, and may extend down to 20 or 30 feet or even more. In the spring of 1900 the auger was lengthened to 25 feet in order that marsh deposits might be more thoroughly tested, and during that season 18 feet were usually used in work on the water.

As most of the lakes examined have a depth of from 30 to 100 feet over most of their area it follows that the examinations on water were confined to the usually narrow belt of shallow water close to shore or over bars, leaving in most cases the greater part of the lake's resources unknown. On the other hand, since practical cement men consider only the marl beneath 15 feet of water or less available with present appliances, it is evident that this deeper water area may, from the practical standpoint, be considered out of the question, and thus our examinations, limited as they were, covered the area of available deposits. For these reasons it is evident that with a given average depth of marl it is not so much the size of the lake

that determines the size of the deposit commercially, as the size of the area of shallow water. Where it is possible to lower a lake or partly or wholly drain it, the available deposit may include everything out to where the water is 10 feet in depth, plus the possible amount of lowering. Many of the lakes, on account of the value of the adjacent real estate being dependent upon the maintenance of a high level, can not be economically lowered. Many have already reached the limit of lowering due to lack of fall in outlet or drainage ditch. Some can readily be lowered from three to ten feet. A few can, by expensive ditching, be completely drained.

In many instances, however, even where the lakes contain large deposits of marl and can be easily lowered, they are far more valuable to the public at large at their present level, than they would be, were their depths decreased and the deposit of marl made commercially available.

The work in the autumn of 1899 was carried on much more rapidly than that in 1900, and but little attention was given to the main features of the lakes themselves, the deposits of marl alone being considered. Usually two, and sometimes three or four deposits, often several miles apart, were examined in a day. As the season advanced much trouble was experienced in securing boats. The results of the investigation of that season are, therefore, in part crude and often irregular, some deposits being examined much more in detail than others. In 1900, with more time at command, the study of the deposits was made more in detail, and many interesting facts relative to the properties and deposition of the marl were secured.

LEGEND.

Figure 01 is explanatory of the details of the marl deposits as shown on the maps accompanying the descriptions of the lakes. The various shades and markings of black indicate a variability in the thickness and location of the marl and muck, as shown by the accompanying figure.

In general, black indicates workable marl, that is, marl having a thickness of over 10 feet and lying out of water or in shallow water, without muck cover. As the maps are all reduced to the same scale, a glance at any map suggests the relative amount of such marl in that deposit. Under the general rule that marl can not be profitably dredged at a depth of more than 15 feet, or removed from beneath more than three feet of muck, the black shows the amount of work-

able marl in each deposit, *without lowering the water level.* Many of the lakes can be lowered so as to render workable a part or all of the area which on the map appears as an unworkable deposit.

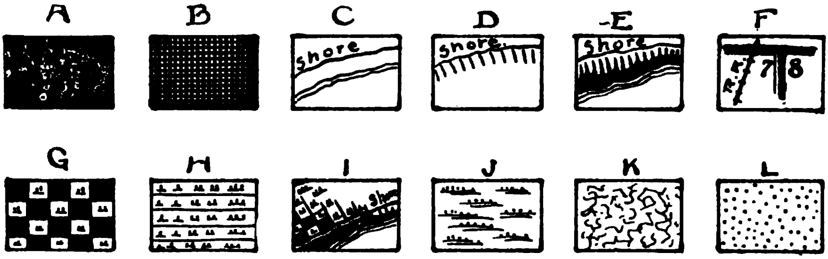


Fig. 01. Legend, Explanatory of Maps of Marl Deposits

A. Marl, dry, or in six feet or less of water, of which the bottom is over 16 feet deep. It thus, in all cases, represents marl over 10 feet deep. In lakes, the outer edge of solid black band, where shown, is supposed to represent the line of six-foot water. As a rule the distance from the shore to the six-foot line is exaggerated.

B. Marl, more than 10 and less than 16 feet thick; not overlain by muck.

C. Line or lines parallel to shore; marl in water over 6 feet deep; the bottom of marl being more than 16 feet below the water level.

D. Marl less than 10 to 16 feet deep. Lines at right angles to shore.

E. Sample map of overshore deposit, interpreted as follows: Marl sets in close to shore, increases in thickness toward the body of the lake, until at half way or a little more to the six-foot water line the bottom of the deposit is beyond reach of sixteen-foot auger, a condition that continues into deep water. The black band suggests the width of marl bed from where the deposit first extends more than 16 feet below water level to the six-foot water line. The lines outside of the black band indicate that marl is still found outside of the six-foot water line with bottom more than 16 feet below water level.

F. Section corner showing road, railroad and numbers designating sections.

G. Deposit, "dry," as in A, except that it has muck over it, the number of uprights in the open squares suggesting the number of feet the muck is thick (in this case, 2).

H. "Dry deposit" marl, less than 16 feet thick, overlain by muck—at left by muck averaging one foot thick; in middle, two feet thick; at right by muck three feet or more thick.

I. Sample map showing at the right a deposit similar to E; at left the marl extends out under shore, with muck overlying, a small area having only one foot of muck above more than 15 feet of marl.

J. Marsh, not explored.

K. Muck in cross sections.

L. Sandy ground, or sandy bottom of lake.


HILLSDALE Co. MICH.
WILLIAMS Co. OHIO

STEUBEN COUNTY.

References.—

1873.—G. M. Levette, Fifth Ann. Rep. Geol. Surv. Ind., p. 440.

1875.—Id., Seventh Ann. Rep. Geol. Surv. Ind., p. 491.

1891.—Dr. C. R. Dryer, Seventeenth Ann. Rep. Dept. Geol. & Nat. Reso. of Ind., p. 114.

1899.—Frank Leverett, Water Supply and Irrigation Papers of the U. S. Geol. Surv., No. 21, p. 27.

This county occupies the extreme northeastern corner of the State of Indiana. It is bounded on the north by Michigan, on the east by Michigan and Ohio, on the south by Dekalb County, Indiana, and on the west by Lagrange County. Its area is 311 square miles. The entire county, except a valley in the southeastern corner, is more than 900 feet above sea level, and it is estimated that more than one-half of the county is over 1,000 feet above, while occasional points rise to 1,150 feet. With the exception of Randolph County, its average height above sea level is probably greater than that of any other county in Indiana. This great elevation is not due to an elevated rock surface but to the heavy accumulations of drift which everywhere cover the underlying sedimentary rocks to a depth of 300 to 600 feet. The deposition of the drift has been in most parts of the county very uneven and has given rise to a remarkable group of rounded hills and irregular valleys, which has rendered the surface picturesque to a degree, hardly surpassed by any county of the State.

As yet the county is but fairly well supplied with transportation facilities. The Fort Wayne branch of the Lake Shore & Michigan Southern Railway enters the county near the middle of its southern boundary and runs through it in a northeasterly direction, leaving it at the station of Ray, three miles west of the northeastern corner. The Chicago division of the Wabash System runs east and west along the southern edge, crossing the L. S. & M. S. at Steubenville. This leaves a large area of the western and northwestern portions of the county distant 12 to 17 miles from a railway. Several electric lines have been proposed through this section, and one or more of them will doubtless be soon constructed.

Steuben is pre-eminently the ranking county of Indiana in the number and beauty of its lakes. They occupy the valleys and depressions due to the irregular deposition of the mantle of drift. Their great variety in size, depth and outline of shore render the

region most delightful for a summer's outing, and the number of visitors annually attracted by their presence is constantly increasing. The waters of most of the lakes are very clear and pure. They are well stocked with the larger game and food fishes, thus furnishing an abundance of sport to visiting anglers and a plentiful supply of cheap and nutritious food to the permanent resident.

In the latest atlas of the county 57 lakes are named, but many of them are mere ponds or "Mud Lakes." Twenty-two of the larger ones were visited while gathering data for the present report. Six deposits of marl sufficient in area and thickness, and easily available under present conditions for cement making, were found in the county. Three additional deposits were of workable size but were mainly beneath deep water. Six of the deposits were found not to be of sufficient size to justify the investment of capital for their exploitation. In a number of instances the marl in or about two, three or four lakes was considered as one deposit, on account of their proximity, and is so treated in the pages which follow.

Finally it may be said that a number of the larger lakes of the county, although underlain with large deposits of marl, are of far more benefit to the community at large, as they exist to-day, than they would be were these deposits developed and used for cement making.

CLEAR LAKE.

Workable Deposit: Largely Under Deep Water.

Clear Lake lies principally in sections 19 and 20 (38 north, 15 east) Clear Lake Township, in the extreme northeastern corner of Indiana. Its northwestern point is about one and one-half miles from Ray, the nearest station on the Fort Wayne branch of the Lake Shore and Michigan Southern Railway.

The lake is broadly L-shaped with a large bay projecting from the southwest. The extreme length from east to west is over one and one-half miles, and from north to south over one mile, with a breadth in each of the arms of about one-half mile. The total area is 600 or more acres. The lake consists of three distinct basins which would become separate lakes if the water surface were lowered six or eight feet. This results from the presence of a broad bar extending from (D)* to (O) and (P).

* See the accompanying map.

It is evident that the low ridge at (D) which is rapidly being cut down, formerly extended south of west across the lake to the island and beyond; the island (F) being but a fragment spared in the planing down of the ridge by wave action. In November, 1899, a majority of the soundings across this bar gave a depth of three feet and none more than five feet on the crest of the bar. The shallow water around the lake is broad, the line of six-foot water running from 50 to 300 feet from shore, with an average of perhaps 150 feet. Outside of that the depth increases rapidly, so that at one point a depth of

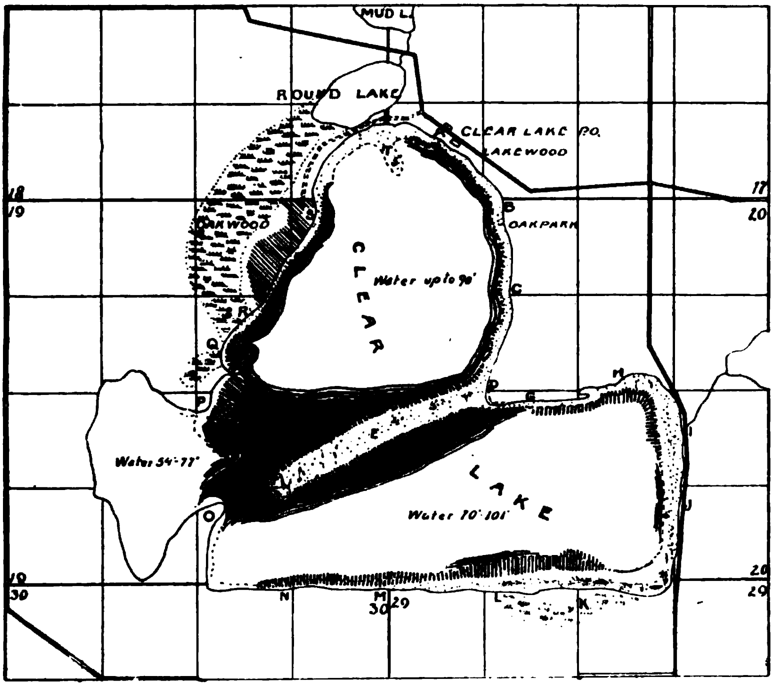


Fig. 1. Map of Clear Lake, Steuben County, Ind.

90 feet was found by Dr. Dryer within 10 rods of the bar. He reports a descent of 30 to 40 feet in five rods at several places, the average slope being not less than one foot in two. The south basin has a maximum depth near a line through the center of from 70 to 101 feet. The bay to the west gave depths of 54 to 77 feet. The north basin has an irregular bottom, and while of less average depth than the southern basin, gave 80 and 90 feet in places.

The fact that, except on the bar mentioned, no marl occurs in water with a depth of less than three or four feet, indicates that the

surface of the lake is higher now than at some preceding period. On the other hand, the broad sandy beach at the eastern end indicates that it has also, for at least a short time, stood at a somewhat higher level than now.

Around most of the lake the banks slope up rather quickly to an elevation of a score or more of feet. The northwest shore is bordered by rather extensive marshes containing spring mounds and small elevated islands. There is also a small marsh near the southeastern corner of the lake. As a rule the shores of the lake are quite clean and free from vegetation. The yellow and white water lilies and pickerel weed occur in isolated patches in shallow water. The pond weeds and chara are of more frequent occurrence. The most conspicuous plant in the lake is the great bulrush, *Scirpus lacustris* L., which thinly covers the bars. The outlet of the lake is to the northward through a small stream which, after many meanderings, empties into the St. Joseph of the Maumee. Two large hotels on the north side of the lake, easily accessible from Ray station, furnish, during the summer, accommodations for visitors, and the place is rapidly growing into a resort for sportsmen, and all who seek clean, safe bathing, and ample boating and fishing grounds.

MARL.—As indicated on the map, the shallow water from (A) to (D) contains no marl. At (A) the marl is five feet deep where the water is four feet, and reaches about 10 feet at the six foot water line. Beyond that the bottom of the marl was not found, the water being 13 feet deep, at 200 feet from shore. Going toward (B) the marl on the six foot line runs under 10 feet and at (B) a fine blue clay replaces the marl in six feet of water. From (B) to (D) no marl was struck in three feet of water or less, and at one point four feet of water found no marl. At most points the marl reaches below 16 feet outside the six-foot water line. The bar running from (D) to (F) contained no marl on its crest as far as examined, the water thereon being from three to four feet deep. A little south of the crest the marl was over 12 feet deep in four feet of water and drillings in five feet of water at points along the south side found, everywhere, over 11 feet of marl.

At (G), in the southern basin, one foot of marl is found 100 feet out from shore in four feet of water, the bottom being hard nearer shore. At 150 feet out the water is eight feet deep and marl over eight feet thick. Going toward (H) the marl runs out in four feet of water at the same distance from shore. Six feet of water 200 feet from shore shows but four feet of marl. About the same con-

ditions continue to (I). At (J) no marl is found in six feet of water, 150 feet from shore, but sets in and deepens rapidly beyond that. At (K) somewhat similar conditions prevail, but the marl does not appear to deepen quite so rapidly, only four feet being found beneath seven feet of water. Toward (L) the marl in seven feet of water deepens to more than nine feet at 400 feet out. The six-foot water line, which extends from about 200 feet to over 300 feet out, shows only three feet of marl, with none toward shore. Toward (M) and (N) the shallow water narrows so that at (N) five feet of water is found 50 feet from shore, with five feet of marl beneath. Between, as at (M), there is only three feet of marl in six feet of water.

Crossing the bar west of the high island (F) the water is mainly three feet deep, though running up to five feet in places. The marl is beyond reach of 16-foot drill all over this area until (P) is approached, where, in four feet of water, only seven feet of marl occurs and still less going north. The area between (P) and (D) was not explored in detail, so that the black shading north or northeast of the island is somewhat questionable. From (P) to (S) the six-foot water line is quite irregular, and where farthest from shore the marl was beyond reach of pole in four or five feet of water at all points tested. At (T) a long shoal projects from the north shore, but no marl was found on it, the bottom being blue clay like that at (B).

The area of marl in the lake is probably 400 acres or more. Of this about 80 acres, averaging 10+ feet in thickness, is beneath shallow water. The remainder is found beneath water 10 feet or more in depth.

CEDAR LAKE.

Not a Workable Deposit.

Two miles west of Clear Lake in sections 22 and 23 (38 north, 14 east), Fremont Township, and just east of the Ft. Wayne Branch of the Lake Shore & Michigan Southern Railway, is what was once called Cedar Lake. It has now been partly drained so that with the exception of a few lagoons its former area is a marsh. As far as examined, all across the north end near the railroad, this marsh was in the form of a floating meadow, barely, or not at all, sustaining one's weight and with water-muck below. Tests made in several places from the shore out 300 or more feet, or as far as seemed safe to go, showed no marl until a depth of over five feet of muck was reached, when marl began to appear. The points farthest out showed about five feet of watery muck and two feet of marl.

Since the lake area, as shown on the older maps, was 400 or more acres, it may be that quite a large area of marl exists near the center of the former lake, but even its proper testing is not, under the present conditions, possible.

LAKE GEORGE.

Large Deposit, Mostly Beneath Deep Water.

This lake lies partly in sections 14 and 15 (38 north, 13 east), Jamestown Township, Steuben County, and partly in Branch County, Michigan. It is about one and one-quarter miles in length by three-

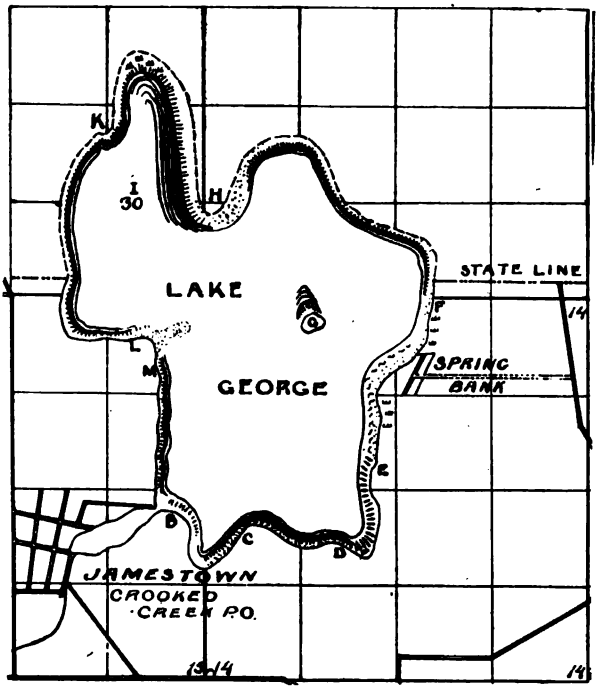


Fig. 2. Map of Lake George, Steuben County, Ind.

quarters of a mile in greatest width. Its outline is somewhat irregular, there being two bays on the north shore, one on the west and two on the south. Those on the north are much the larger and are formed by a long point of projecting land. The northwestern bay is the longer, while that on the northeast is the wider and contains the deeper water. The level of the lake was raised four feet in 1836 by the building of a mill-dam at its outlet, Crooked

Creek, near the southwestern corner. A good water-power mill, erected in 1862, is still in operation at this point.

Northeast of this mill, on the southwest shore of the lake, is a handsome grove now much frequented by picnic parties. East of this grove the banks are lower and the adjacent fields are cultivated. Along the southern third of the eastern shore there is a long, low wooded stretch of territory. North of this the eastern bank is high and sparingly wooded, forming an excellent site for cottages, of which quite a number have been erected at Spring Bank. In front of these the shore and bottom are of gravel, with many good-sized boulders intermingled. A fine spring, flowing 40 gallons or more per minute, runs into the lake from a height of 10 feet above the water level. Immediately north and south of Spring Bank a muck meadow, 10 to 20 rods in width, intervenes between the edge of the water and the margin of the wooded hills. This would indicate that the level of the lake was once at a sufficient height to cover the present meadow area. In the northwest corner of the northeastern bay a lagoon extends back in which there is much muck and aquatic vegetation, as spatterdock, cat-tails, etc. The long lobe of land extending into the lake from the north, has its eastern bank low, with stumps of trees out in three and four feet of water. The western bank is of gravel and rises eight feet above the water level. It is well wooded and offers fine sites for summer cottages. The northwestern bay extends about one-third of a mile north from the southern point of this lobe. Its shores are low with much aquatic vegetation along the margins. The same is true of the western shore of the lake. A long point, covered with rushes, puts out at (L) and forms the bay to the north.

On account of limited time no lines of detailed soundings were made. Dr. Dryer reports that "The main body of water was found to have nearly a uniform depth of from 50 to 60 feet, sinking to 80 feet a little south of the center, the depth being far in excess of what might be expected from the character of the shore."

MARL.—Around the south and west shores the area of shallow water marl is not wide. Opposite (B), 100 feet from shore in six-foot water, the marl was six feet thick. Two soundings, 150 and 250 feet from shore showed respectively 26 and 38 feet of water. Opposite (C), 75 feet out, the marl was beyond length of 18-foot auger in seven feet of water. Between (C) and (D), 150 to 200 feet from shore, the bottom of marl was reached but once in six-foot water, while three-foot water had gravel bottom beneath. The

greater part of the southeastern bay is underlain with marl ranging up to 12+ feet in thickness. Opposite (E), 200 feet from shore, only five feet of marl occurs beneath six feet of water, but it deepens to beyond 11 feet in seven-foot water. Between (E) and (F) only a very tenacious blue mud occurs beneath six and seven feet of water. Near (G) one-third of the way across the lake, were several stakes, denoting fishing places, which were sunk into the marl—here 10+ feet thick beneath eight feet of water. Beyond (F) the marl sets in 200 feet from shore in five-foot water, but it is dark-colored or mucky. It gradually thickens and 150 yards out it is 11+ feet thick beneath seven feet of water. Southeast of the point (H) gravel bottom only is found in seven-foot water. Going westward one-third of the way across the northwest bay, a fine quality of marl was found 10+ feet in thickness at several points beneath eight-foot water. One-half way across near (I) the water was 30 feet in depth. One hundred yards north, a growth of rushes denotes another area of shallow water, but it was nowhere less than eight feet deep with 10+ feet of marl beneath. Opposite (K), 100 yards from shore, on the six-foot water-line, 12+ feet of good marl occurs. North of this muck sets in and covers much of the bottom of the shallow water area. Coming south between (K) and (L) 12+ feet of marl is found everywhere on the six-foot water-line. The rush-covered point at (L) is, however, composed of gravel, and no marl was found in eight-foot water, east or south of its extremity. Between (M) and (B) the marl sets in again and was everywhere found beyond reach of pole at the six-foot water-line.

From the above facts we judge that at least two-thirds of the original lake area is underlain with 12 feet or more of marl of a good quality. It seems to be lacking over part, at least, of the eastern third of the former water area. The deposit is not deemed available for cement making with the present facilities for securing marl beneath deep water.

HOG LAKE.

Workable Deposit, Partly Under Deep Water.

Hog Lake lies two miles west of the village of Jamestown and occupies part of section 17 (38 north, 13 east), Jamestown Township. Its northern border is about 50 rods south of the Michigan line. The water area of the lake was lowered about eight feet in 1896, by a ditch cut from it northward into Walters Lake, so that the present area covered by water is probably not over 70 acres. The immediate

shores of the lake are, except on the east, everywhere low and marshy. On the south and west, the marshes gradually rise into higher, cultivated land. The eastern shore is, for the most part, composed of a gravelly ridge which a few rods back from the water's edge rises to a height of 15 or more feet. On the north a level marsh, 50 rods wide, separates Hog Lake from Walters Lake, the latter lying in Michigan just north of the State line. On the northwest is an extensive tamarack swamp. An island of five or six acres, thickly covered with tamarack, birch and alder, lies a little south of the center of the lake. Since the latter was drained the channel

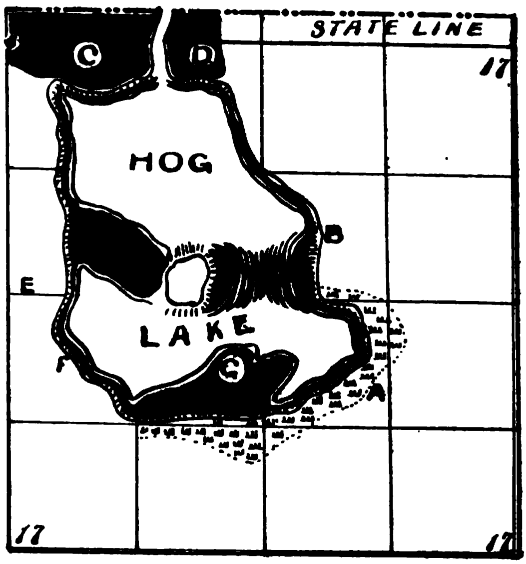


Fig. 3. Map of Hog Lake, Steuben County, Ind.

west of the island has become choked with vegetation, and a continuous marsh now exists between the island and main land. A long marshy point puts out from the south shore to the northeast, thus dividing the water, at present existing in the lake, into three lobes. Among the mollusca noted in Hog Lake were *Anodonta grandis* Say, *Unio luteolus* Lam., *Physa heterostropha* Say, *Campeloma decisum* Say and the *Helisomas trivolvis* and *bicarinata* Say.

The greatest depth of water found was north of the island where three soundings, 10 rods apart, showed respectively, 32, 35 and 33 feet. The southeast lobe of water runs up to 24 feet in depth, while no sounding in the southwest lobe showed over 15 feet.

MARL.—The area of shallow water along the east and north sides of the lake is not wide. A belt of rushes, *Scirpus lacustris* L. five to ten rods in width fringes these shores and wherever tested, in depths of four to six feet, the bottom of marl was not found with an 18-foot auger. The tests were usually made near the outer edge of the rushes where the bench of marl began to dip rapidly beneath deeper water. The water directly east of the island in the middle of the channel was but eight to 10 feet deep, and in it bottom of marl was nowhere reached. At only one point (B), opposite north end of the island on the east shore was bottom reached in three feet of water. Here, with 21-foot auger, the marl was found to be 16 feet thick, with gravel beneath. Along the north side, in two feet of water 75 feet from shore, the bottom of marl was reached at depths varying from 11 to 17 feet. Marl forms the surface of a large portion of the marsh, (C) and (D), between Hog and Walters lakes. At no place was it less than 14 feet thick and the large majority of tests showed more than 21 feet. On the west side of the drainage ditch, half way between the two lakes and five rods east of the border of tamarack, it was 16 feet thick beneath one foot of muck, but at the edge of the tamarack was not found. From the tests we judge that this marsh of 20 or more acres is underlain with marl of an average thickness of 18 or more feet. Walters Lake, 30 rods wide by 70 rods long, is said to be also wholly underlain with marl. Being in Michigan, it was not tested, except along its south shore, where the marl was 21+ feet in depth.

Along the eastern side of Hog Lake, north of the island, the marl was everywhere 18+ feet in depth in three-foot water. East of the lake and north of the half-section line, at (E), is a marsh of about 20 acres, over much of which the marl forms the surface. Seven bores were put down on this marsh which showed the marl at the water's edge to run from 15 to 21+ feet in thickness. Near the north end of the marsh, and 10 rods west of the lake's margin the marl was still 21+ feet, while within five rods of the western margin of the marsh it was eight to 12 feet deep. On the north side of the island, at the edge of the rushes, 75 feet from shore, the marl was 13 feet thick beneath two feet of water. It was 15 feet thick at several places along the south side of the island and at (F) on the west shore of the lake southwest of the island was 18+ feet in three feet of water. At (G) it had increased in thickness to 20+ feet and the larger part of the marsh and the shallow water area between (G) and (A) was underlain with a deposit 20 or more feet deep.

Taking into consideration the marl in and about Walters Lake, we have here a first-class workable deposit. The two lakes can, with little expense, be lowered so that the larger part of the marl now in water over 10 feet in depth, will become available. The only drawback to this deposit is its distance from transportation facilities, the nearest railway being seven miles to the eastward.

An analysis of an *average* sample of the Hog Lake marl showed its composition to be as follows:

Calcium carbonate	90.42
Magnesium carbonate	2.88
Alumina	.14
Ferric oxide	.28
Insoluble inorganic matter (silica, etc.)	.68
Organic matter	4.13
Total	98.53

The marl is thus proven to be of excellent quality. The percentage of organic matter is a little high, but this was probably due to the method of securing the samples. The organic matter is destroyed during the process of burning into cement, and the amount present, when less than six per cent. has, therefore, little or no effect.

LIME LAKE.

Workable Deposit.

Lime Lake lies about one mile northwest of Orland, in section 18 (38 north, 12 east), Mill Grove Township. In shape it is oval, and at present has but about 15 acres of water surface. The greatest depth is 26 feet, but most of the water is under 10 feet, and from a distance looks like milk on account of the reflection from the white marl at the bottom. The lake lies in a narrow valley between hills 30 or more feet in height. On the west is a marsh five to eight rods in width. On the north and south the marsh extends for a long distance up and down the valley. On the east the water reaches the base of a ridge of gravel. No vegetation, not even *Chara*, exists at present in the water. The outlet of the lake is a small stream which flows from Anderson Lake, 30 rods north of the State line, southward through Lime Lake and empties into Crooked Creek. The marsh land, mentioned below, lies on both sides of this stream.

Marl.—On the west, north and south sides of the lake at the water's edge, the marl is, with one exception, everywhere more than

25 feet thick. It also exceeds that depth in the marsh to the south of the lake as far as the road, beyond which it was not tested. At the extreme southeastern corner of the lake within 20 feet of the gravelly ridge, it was but six feet thick, with gravel beneath. Along the east side in three feet of water, 70 feet from shore, it was 18+ feet in thickness.

In the marsh to the north, which is over three-quarters of a mile in length and 20 to 30 rods in width, the marl comes to the surface in a number of places, and, five rods out from the foot of the bordering hills, was almost universally found to be more than 21 feet in thickness. In a few places it is overlain with muck one to two feet thick. The upper three or four feet of the marl beneath the muck

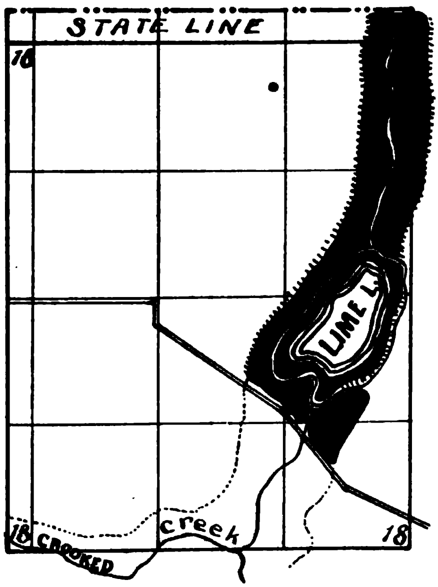


Fig. 4. Map of Lime Lake, Steuben County, Ind.

was here, as elsewhere, darker than that in the lake, on account of the sediment from the decaying grass and other muck-forming vegetation, soaking through it. Anderson Lake, north of the Michigan-Indiana line, is said to be somewhat larger than Lime Lake, and wholly underlain with marl which in places has been tested and found to be more than 35 feet thick. It was not visited by us.

The marl of Lime Lake is, in appearance, very white and pure. It was, in the early settlement of the country, burned for lime. Dr.

Dryer, who visited the lake in 1890, made a chemical analysis of a sample of the marl which showed its constituents to be as follows:*

Calcium carbonate	86.00
Magnesium carbonate	9.42
Iron carbonate	1.16
Silica	1.08
Organic matter	2.32
Total	99.98

The amount of magnesium carbonate found was in excess of that of any marl of which analysis has been made in the State, and it is very probable that a mistake was made in its computation. The other impurities are very few, and aside from the magnesium carbonate the anaylsis indicates a deposit of high grade.

Taking into consideration the acreage of marsh marl, above and below Lime Lake, and also the great average thickness of the bed, there is here a good workable deposit, which will doubtless become utilized whenever transportation facilities are secured.

SHALLOW, DEEP, LITTLE AND BEAVER-DAM LAKES.

Workable Deposit.

These four lakes are connected by a narrow stream and so form a chain which occupies a valley in the western half of sections 6 and 7 (37 north, 12 east), Jackson Township. They are about 12 miles east of the Grand Rapids & Indiana Railway, 11 miles west of the Fort Wayne Branch of the L. S. & M. S. Railway, and the same distance north of the Chicago Division of the Wabash Railway.

Beaver-Dam Lake, in the northwestern quarter of section 6, is one-half mile long by about 30 rods wide, and occupies a narrow valley between two parallel ridges. Its greatest depth is said to be 26 feet. Little Lake is nothing more than a large pond in the southwest quarter of the same section. Its water area is about six acres and its margins are thickly covered with rushes and other water-loving vegetation. These two lakes were not visited, but it was said by the residents of the vicinity, that their bottoms and margins were composed wholly of marl of great depth.

Deep Lake, in the northwest quarter of section 7, has a water area of about fifteen acres and a maximum depth of 28 feet. Its southern shore is less than 30 rods north of the northwestern corner of Shallow Lake. Its shores are low and surrounded by marsh.

*17th Ann. Rep. Ind. Geol. Surv., 1891, p. 124.

Shallow Lake lies near the center of section 7. It has been recently drained by a ditch running to the southwest, so that in September, 1900, its water area, of about 60 acres, was nowhere over two feet in depth, though one in wading was apt to sink deeper on account of the softness of the marl bottom. Its shores are low and surrounded by a wide marsh except on the east, where, 10 rods from the edge of the water, a gravel ridge rises 20 feet above the lake. From the side of this ridge, opposite the middle of the lake, two fine springs emerge about 10 rods apart. The larger of the two has a flow of at least 150 gallons per minute, and the other one-half as much. The only aquatic vegetation in the lake, other than scattered bunches of rushes, was about a half-acre of cat-tails, near the southern end of the eastern shore.

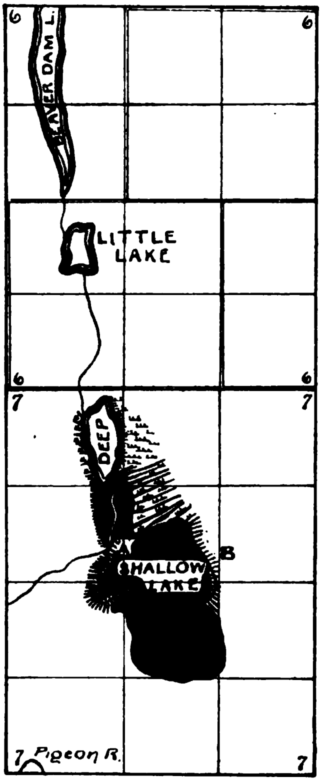


Fig. 5. Map of Shallow, Deep, Little, and Beaver Dam Lakes, Steuben County, Ind.

MARL.—On the north, west and south shores of Deep Lake, the marl at the edge of the water is everywhere more than 21 feet thick. The bottom shelves off rapidly into 10-foot water. The marsh on the west is but about 12 rods wide, and over most of it the muck is two feet deep and underlain with marl, which diminishes gradually in thickness from the edge of the lake to the margin of the hill. On the marsh, between Deep and Shallow lakes, the marl forms most of the surface and is 21+ feet in depth. At the northwest corner of Shallow Lake one bore was put down with a 25-foot auger which did not reach bottom of marl. At (A), thirty rods southwest and 50 feet from the former edge of the lake, it was 15 feet thick with gravel beneath. Along the entire west shore the marl was found to be 21+ feet, six to eight rods out from the former shore but gradually diminishing to 13 feet at the old margin of the lake. On the south shore bottom was nowhere reached at 21 feet, and a number of tests showed that the greater part of the 30 acre marsh south of the lake is underlain with marl of an equal thickness. On the east side of

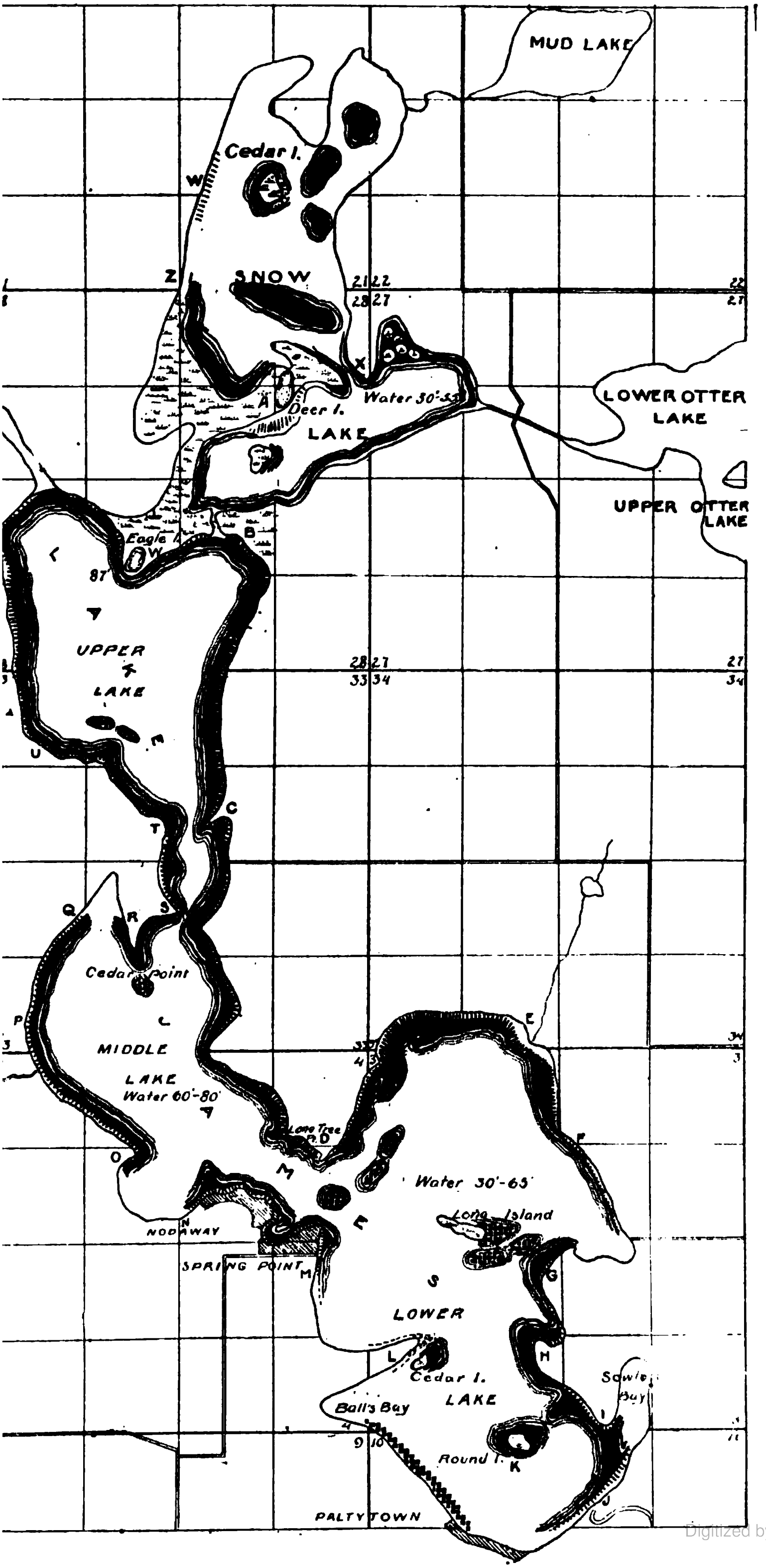


Fig. 6. Map of James Lake, Steuben County, Ind.

the lake, on account of the proximity of the gravel ridge, the marl is not so thick, being but nine feet at the margin of the former lake, and 15 feet six rods out from shore. Between the springs, at (B), and the lake, the marsh, 10 to 15 rods wide, is covered with a fine wire-grass and underlain with marl 15 feet or more in depth, while at the edge of the water it is 21+ feet. The marsh northeast of Shallow Lake and east of Deep Lake is 60 rods long by 40 wide, and covered with wire-grass. The surface is of muck two to six feet thick. The southern half is underlain with marl from four to 15 feet in thickness, but beneath the muck of the northern half only sand was found. Along the east margin of Deep Lake the marl was 21+ feet thick.

An analysis of an average sample of the marl from this deposit resulted as follows:

Calcium carbonate	93.29
Magnesium carbonate	2.67
Alumina	.04
Ferric oxide	.12
Insoluble inorganic matter (silica, etc.)	.47
Organic matter	1.56
Total	98.15

This shows the marl of Shallow Lake to contain the highest percentage of calcium carbonate of any deposit in the State, of which analysis was made. The acreage and thickness is sufficient to justify the investment of capital for the purpose of cement making, and there is little doubt but that the deposit will be so utilized in the future.

JAMES LAKE.

Two Workable Deposits; One Largely Under Deep Water.

Lake James lies in sections 21, 22, 27, 28, 33 and 34 (38 north, 13 east), and sections 3, 4 and 10 (37 north, 13 east), in Johnson and Pleasant townships. Its southern shore is three miles northwest of Angola, but the Fort Wayne Branch of the L. S. & M. S. Railway to the east can probably be reached in two miles. It is the third largest lake within the State, being exceeded only by Lake Wawasee, Kosciusko County and Lake Maxinkuckee, Marshall County. The total length of James Lake is nearly five miles and its average width about one-half mile. It covers an area of about 1,670 acres. In shape it is very irregular, lying mainly in a north and south line, but

divided into five basins, separated from each other by narrow and often shallow channels.

The most southern basin, known as the "Lower Lake," is about one and one-quarter miles in length from north to south and three-quarters of a mile in extreme width, with a very irregular shore line, running back to form several prominent points and embayments, as Sowles, Ball's and other bays. The maximum depth of the Lower Lake is 65 feet. Half way between the southeast shore and Round Island the depth was 40 feet; 200 feet west of the island, it was but 18 feet, while 100 yards east of the cottages at Spring Point it was 32 feet. Three small islands, Long, Round and Cedar, project above the water and several shoals nearly reach the surface. These facts indicate that the bottom of the lake is very uneven. In like manner, the area of shallow water along the shore is quite irregular in places, as at (F) being very narrow, while from (D) to (E) and (G) to (J) it projects out in long and often broad points several hundred feet from shore, making the average width of shallow water over the stretches named, probably, 200 feet. The shores on the south side of this basin rise rather abruptly 30 or more feet and are heavily wooded with oak and hickory. Those on the east and northeast are much loftier, reaching a height, in places, of 100 or more feet. On the west, between Spring Point and Ball's Bay, the shores are much lower and the adjacent fields are, in part, cultivated.

The next basin north of Lower Lake is known as "Middle Lake." It is really the foot of the entire lake, as the outlet, Crooked Creek, flows from it into Jimerson Lake. This basin is separated from the preceding by a rather narrow strait between Lone Tree Point and Spring Point, in the center of which was formerly an island, now a shoal. Northwest of this shoal, near the point indicated by the letter (M) on the map, the water was 32 feet in depth; 100 yards farther northwest it was 56 feet; while a third sounding, the same distance north from the second, showed 63 feet. A fourth, 200 yards north from the third, and about the middle of this basin east and west, gave 72 feet, the greatest depth found in Middle Lake, though Dr. Dryer reports 80 feet as the maximum. The band of shallow water around this basin is narrow and as a rule quite regular. A small shoal exists just south of Cedar Point. Middle Lake is about a mile long by a third of a mile wide. The shores are more regular, though two bays or points put out from it. The hills on the east rise abruptly from the water, are heavily wooded, and 40 to 60 feet in height. To persons willing to climb, their crests contain many ideal sites for summer cottages. The shore at the northwest corner is low and marshy.

The remainder of the shore line slopes upward and backward into low wooded hills.

The third basin or "Upper Lake," is reached through a narrow channel with only two or three feet of water over the bar or spit of sand which puts out from the west shore. This basin is a mile long by three-quarters of a mile in greatest width. A depth of 87 feet of water, the "deepest sounding in the lake," is reported by Dr. Dryer to have been found a few rods west of Eagle Island, which forms part of the north shore of this basin. The greatest depth found by us was 78 feet.* The belt of shallow water in Upper Lake, particularly along the east side, is broader, ranging from 100 to 300 feet in width. The east shore, like that of the two basins to the south, is densely wooded, but the hills rise only about 30 feet. The west shore is of rounded hills of clay and gravel, bare of timber, and, near the northwest corner, sloping gradually upward to a height of 100 or more feet.

From the north of Upper Lake, an unbroken expanse of water formerly extended a mile and a half to the northeast. Now the encroachments of vegetation have nearly cut this off to form a separate lake, known as *"Snow Lake."* This is also nearly divided into two separate basins. A channel, only about thirty feet wide and difficult to find, runs through the marsh to the east of Eagle Island, and admits the passage of a row-boat from Upper Lake to the south basin of Snow Lake, the longer axis of which extends northeast and southwest and is continuous on the east with the valley of Otter and Marsh lakes. This basin is three-quarters of a mile long by one-sixth of a mile wide and is separated from the much larger northern basin by a long marshy point from the northeast, and by Deer Island and a bar to the east of that island covered with a growth of rushes. Several soundings from west to east through the middle of the basin gave the following depths in feet: 78, 54, 40 and 36, the first and deepest being south of Deer Island. This island rises 40 feet above the water, contains an area of about three acres and is heavily wooded with oak and other timber, forming one of the prettiest spots about a lake which is far above the average in picturesque beauty. Deer Island, as well as Eagle Island, are now both connected with the main land by extensive marshy meadows. Along the south side of this basin the shallow water area is from 10 to 20 rods in width. At the inlet from Otter Lakes the valley is broad, it being evident that at one time the lower part of Snow

*This was near the point occupied by the letter "u" of "upper" on the accompanying map.

Lake extended east so as to include upper and lower Otter Lakes and Marsh Lake, the latter about two miles to the eastward.

The waterway at present connecting the North and South basins of Snow Lake is a channel about 10 rods wide between the marshy point at (X) and the extremity of the bar east of Deer Island. The North basin is very nearly a mile in length from north to south and not quite one-half mile in average width. A peninsula-like point of land juts into the water from the north shore, forming two bays, the eastern one of which is much the wider and receives Crooked Creek, the outlet of George and Mud lakes. A small island, less than an acre in area, and covered with wire-grass and cat-tails, rises three feet above the water about 40 rods south of the extremity of this peninsula. Betweeen the island and the west shore the water is 32 feet in depth. Twenty rods southwest of the island a shoal 10 rods wide, and thinly covered with rushes extends in a southeasterly direction almost across the lake basin. The water over this shoal is but 10 to 18 inches deep. West of the shoal two soundings gave respectively 48 and 36 feet of water. In the southwest bay, northeast of Deer Island, two additional soundings showed 33 feet and 52 feet; while on a north and south line across the lake, 20 rods east of Cedar Island, not over 32 feet of water was found. The east shore of this basin is wooded, but the hills slope back gradually and rise but 20 to 30 feet above the water. The shores of the northeast bay are, for the most part, low and marshy. The northwestern bay has a narrow muck meadow between the water and the adjoining hills. At several points northwest and west of Cedar Island, the muck banks rise abruptly three feet and more above the water. The greater part of the west shore is bordered with marsh, varying in width from 10 to 30 rods, and covered with wire-grass and other vegetation. Back of the marsh are steep, densely wooded hills, rising 150 feet or more above the level of the lake.

Except in a few localities, mollusca were not plentiful in James and Snow lakes. The only univalves taken were *Helisoma trivolvis* and *H. bicarinata* Say, which were common in shallow water near shore. One of the bivalves, *Margaritana marginata* Say, found in Snow Lake, is noteworthy in that this is the only lake in which it was seen. The specimens were plentiful just south of Cedar Island and were of large size. Other bivalves were *Unio luteolus* Lam., *Anodonta footiana* Lea, *A. grandis* Say, *A. salmonia* Lea, and *A. edentula* Say, all of which were seen in small numbers; *U. luteolus* being the most common and of very large size.

The waters of the lower and middle basins of Lake James are quite free from vegetation. In the channel connecting the Middle and Upper basins as well as along the east shore of the latter, the eel grass, *Vallisneria spiralis* L., grows in abundance, as do also several species of pond-weed (*Potamogeton*), and the two rushes, *Scirpus americanus* Pers. and *S. lacustris* L., the latter growing in water up to seven feet in depth. The newer portions of the marsh north and east of Eagle Island are covered with cat-tail, *Typha latifolia* L., while several species of marsh grasses and sedges thickly cover the older portions. The channel west of (B) runs between dense masses of spatterdock, *Nymphaea advena* Sol., broad-leaved arrowhead, *Sagittaria latifolia* Willd., and cat-tails. In the northeastern corner of the southern basin of Snow Lake the white water lily, *Castalia odorata*, and the spatterdock are both abundant. In the shallow water areas of the north basin, both along shore and over the shoal-like islands of marl which rise nearly to the surface, the eel grass and various species of *Potamogeton* grow in profusion. In fact Snow Lake contains as much aquatic vegetation within its bounds as do all the other basins of James Lake combined. In the words of Dr. Dryer: "The group of lakes, including James and its companions, furnish about ten miles of boating, every rod of which is rendered delightful by repeated surprises and a changing variety of picturesque scenes which rival on a smaller scale Lake George, the gem of the Adirondacks, and the famous Thousand Islands of the St. Lawrence. The region around it might be fitly characterized as the Alps of Indiana, and although alpine only in miniature, is worthy to attract more attention than it has yet received. It needs only to be better known to become a favorite resort for many who now travel hundreds of miles in search of the beautiful and the picturesque."*

MARL.—Around the Lower, Middle and Upper lakes at nearly every point examined marl was found, and in general deepened rapidly from shore, so that in no case was marl in four feet of water found to be less than 12 feet thick, and generally the bottom of the marl was not reached at 16 feet in two feet of water, and on the broad shallow bars not in one foot or six inches of water. Along much of the shore of the lake, particularly in the shallower water, the marl is markedly concretionary on top and often for three or four feet down. In places these concretions are like coarse grit, elsewhere they are like small gravel. Again they increase to a flattened diameter of several inches, and resemble geodes externally. The formation of these concretions and the incrusting of shells in this

*17th Ann. Rep. Ind. Geol. Surv., 1891, p. 123.

and other lakes has already been mentioned under the general heading of the "Deposition of Marl." This concretionary structure might easily be mistaken for gravel, for often the drill for the first three or four feet was forced through it with much difficulty. In places the encrusted shells are just scattered here and there on the bottom, but at other places, notably along the east shore of the bay north of Eagle Island, make quite a thick layer. Here also the pebbles of lime were thrown by wave action in windrows along the shore.

The width of the shallow water around the lake has already been described or is indicated on the map. At the mouth of a little branch from the northeast at (E) the marl is rather shallow, only four feet being found in three feet of water. The bar running from (I) to (J) across the mouth of Sowles Bay was thought to be hard bottom when tested, but the discovery a little later that a similar hard bottom was an unusual thickness of concretionary marl led to the theory that we had been in error and that the bar, like the rest of the shallow water, was deep marl. It is so mapped, though it was not retested. The shore from Paltrytown to Ball's Bay was not tested, but is reported to show a good breadth and thickness of marl. The marl off the point at (L) is shallow, three feet being found in six inches of water. At the east side of Cedar Island it was 14+ feet in two feet of water.

The tests for marl in September, 1900, were mostly on Snow Lake, and were made with an auger 18 or 21 feet in length. However, a few were made along the east shore of Upper Lake. These showed that between (C) and (B) the marl was everywhere 18+ feet in two and three feet of water. Southwest of (B) there is an area of 20 or more acres of this shallow-water marl. In the bay north of Eagle Island is one of the finest deposits in Upper Lake. In a number of places in one foot of water 10 feet from shore the marl was 18+ feet and of excellent quality. There is little doubt but that the greater part of the marsh area, 60 or more acres, to the east and northeast is similarly underlain.

An analysis of an *average* sample of the marl from the three lower basins of James Lake gave the following results:

Calcium carbonate	92.41
Magnesium carbonate	2.38
Calcium sulphate	.15
Ferric oxide	.29
Insoluble inorganic matter (silica, etc.)	1.16
Organic matter	1.97
Total	98.36

PLATE 8.

a

a b

Illustrating Concretionary Forms of Marl, Found in James Lake.

(a) Showing gradual incrustation of shells of *Unios*.
(b) Showing nodular concretions caused by low type of freshwater alga growing in masses or colonies.

This analysis shows the marl to be of superior quality; the percentage of carbonate of lime being above the average. Dr. Levette states that "A heavy deposit of lime or 'marl' on the west margin of James Lake was, in the early settlement of that region, worked for lime for making mortar; the marl pits are still visible."* This fact is, in itself, a good evidence of its excellent quality, for only the purest deposits of marl were used by the early settlers for lime making.

It is estimated that there are at least 200 acres of marl 10 feet or more thick beneath less than six feet of water in the three lower basins of James Lake. It is, however, much strung out along the shore. The deep water of these basins is also very probably almost wholly underlain with a thick deposit. Due to the mill below and the large number of cottages along the lake, it is doubtful if its waters will ever be lowered. Indeed it is hoped that no endeavor will be made to lower them, for the lake is far more valuable to the citizens at large in its present condition than it would be were its water area diminished in an attempt to secure the marl beneath its depths.

The area of shallow water marl in Snow Lake is proportionally much larger than in the lower basins of James Lake. This is due to the fact that there are many shoals, or subaqueous islands, which rise to within a foot or 18 inches of the surface, and which are composed wholly of an excellent quality of marl 18+ feet in thickness. These shoals are scattered over the northern and eastern portions of the north basin.

Between Cedar Island and the northwest shore, the marl is everywhere present in shallow water, being 18+ feet in thickness in two feet of water. Where the muck banks rise perpendicularly from the water the marl is nine feet thick and underlain with gravel at the edge of the bank. That portion of Cedar Island below the level of the surrounding water is composed of marl 19+ feet in thickness on the western side, and eight to ten feet on the eastern. The long shoal, 10 rods or more in width, which reaches nearly across the lake basin, southwest of Cedar Island, is underlain with marl 18+ feet thick and very white in color. Between (Z) and the north end of Deer Island the shallow water area is from 5 to 25 rods in width; the bottom of marl in no place being reached with 18-foot pole. South of Deer Island, 100 feet from shore, the marl was 13 feet thick in two feet of water, with gravel beneath.

*Seventh Ann. Rep. Ind. Geol. Surv., 1875, p. 491.

At the western end of the south basin at the edge of the marsh, the marl was 18+ feet, 20 feet from shore in three feet of water. Along the southern shore of this basin the shallow water area, 10 to 20 feet in width, is all underlain with marl to beyond reach of 18-foot pole, except close to shore where the marl runs from five to 12 feet in thickness. In the northeast corner of the same basin, there is a large shallow water area, in which muck from one to two and a half feet thick overlies 14+ feet of marl. A similar area five to 10 rods in width is found along the south side of the long marshy point separating the two basins. At (X) there is 16+ feet of marl beneath two feet of water. The same thickness is found on the west side of the channel. On the east side of the north basin, the shallow water marl ranges in thickness from five to 16+ feet, except along the east shore of the bay which receives Crooked Creek, where it is largely replaced by muck.

Taking into consideration its great average thickness, the deposit of shallow water marl in Snow Lake alone is of workable size, and would fully justify the erection of a large Portland cement factory. The quality of the marl is also of the very best, fully equalling that of James Lake, an analysis of which is given above.

CROOKED LAKE.

Workable Deposit, Mostly Under Deep Water.

Crooked Lake lies in sections 6, 7, 8, 9, 16 and 17 (37 north, 13 east), Pleasant Township. It is about three miles northwest of Angola and somewhat less from the Fort Wayne Branch of the Lake Shore & Michigan Southern Railway. The lake was originally bottle or gourd shaped, but is now practically divided in two at the east side of section 7. The main part, or the part east of this, is divided into two lobes by a long point from the north. The part west of the road, in section 7, is really a long narrow neck nearly choked with vegetation. The total area of the lake is about 950 acres, of which the eastern lobe has about 400, the middle 225, the western 325 acres.

The eastern basin is nowhere deeper than 30 feet and contains much shallow water. From (C) on the east side a broad hammer-shaped bar extends out half way across the lake. The water here is nowhere more than two feet in depth, even on the part farthest out. Just west of it is a small island or shoal. From the west shore at (R) extends out a broad bar bending to the north. Over much of

this the water is only six inches to one foot in depth. The point of land from the north is continued out some distance to the south in a long shoal. The shallow water belt from (A) to (B) is usually less than 100 feet in width.

In the middle basin there is a large area of shallow water just west of the end of the point from the north. At the western end the embayment (K M I H) is now nearly filled up, being practically shut off from the lake by a marl bar. The northwestern lobe is very shallow, in places being readily crossed by wading.

Though abrupt in places, the banks are neither as high nor as steep as those around much of the neighboring Lake James. In

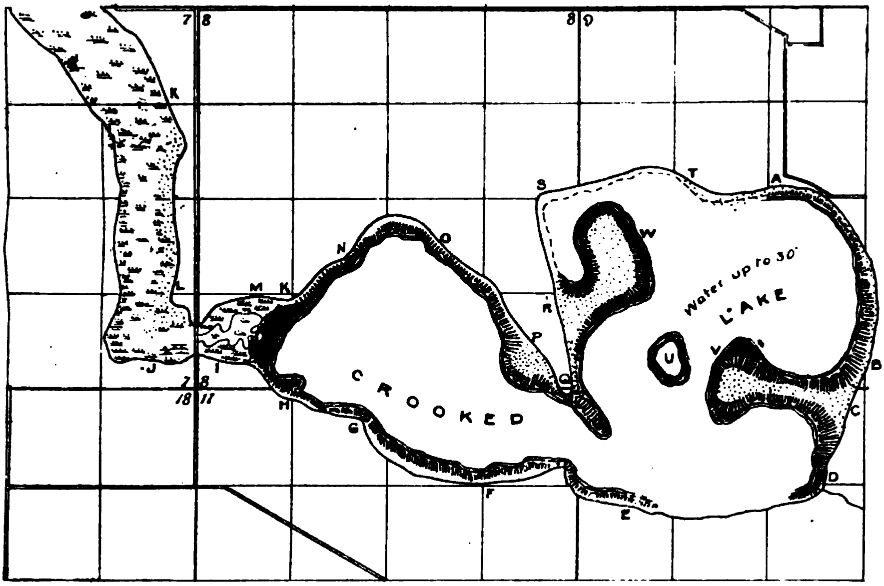


Fig. 7. Map of Crooked Lake, Steuben County, Ind.

places they rise from 50 to 70 feet above the water level of the lake. At several places along the east shore is a broad sandy beach very popular with bathers.

MARL.—From (A) to (B) the shore is sandy to a depth of one or two feet of water. At 25 feet from shore the water is three or four feet deep and the marl from one to five feet thick. Toward (A) there is usually some sand over the marl, often six inches or more, giving the impression that there is no marl present. The six-foot water line runs from 50 to 100 feet from shore and beyond it the drill at no point reached the bottom of the marl, indicating quite a

rapid thickening of the deposit. The long point running out from (C) has no marl on its crest, but on the flanks of the point the marl rapidly thickens up. In the bay enclosed by the point on the south the water is shallow. Running west from a little south of (C) no marl is found in two feet of water. In three feet of water 75 feet from shore the marl is three feet thick. It is six feet thick from where the water is four feet deep to where it is over seven feet deep, but in nine feet of water several hundred feet from shore the bottom could not be reached with a 16-foot pole. At (D) the marl was over 13 feet deep in three feet of water quite close to shore. Due to the breaking of the drill the tests from (D) to (H) were made with only a nine-foot drill. Sand and gravel occur near the shore at (G) and there is only three feet of marl in four feet of water, but at all other points the bottom of the marl was not reached in three or four feet of water. From (H) to (K) is a marl beach with a channel cut through to the crest. The marl at every point tested was over 16 feet deep. West of this toward the road it appeared to be all marl but was too soft to wade, so was not tested. The southern end of the western basin at (J) is a floating meadow underlain with marl beyond reach of 16-foot pole. Only a short distance north there is hard bottom nearly if not quite clear across and tests between (L) and (K), made by wading, gave only hard bottom. From (M) to (N) the marl is, variable. In places there are over 13 feet in three feet of water; in others, only one foot. At one point four feet of water has only seven feet of marl beneath. From (N) to (P) the marl is thinner, the bottom near shore being hard and at several places along the six foot water line the marl was only three feet deep with one foot of marl in four feet of water. In other places five feet of water showed from five to seven feet of marl. Marl is wanting over most of the broad shoal between (P) and (Q), but occurs around the edges, running from six to 10 feet deep in three to four feet of water. The subaqueous point running out from (Q) showed eight feet of marl with three feet of water. The center of the shoal (U) was not examined, but marl is probably not found there, as only nine feet of marl was found in four feet of water on the west side. The center of the bar from (R) to (W) shows no marl, but the marl deepens rapidly around it, so that the bottom is below 16 feet in three and four feet of water. From (A) to (T) the bottom is sand and boulders with no marl in 16 feet or less of water. At (T) marl sets in again, there being about six inches in four feet of water increasing to nine feet at the six-foot water line.

Dr. G. M. Levette, who visited Crooked Lake in 1875, made the following statement concerning the marl: "In this lake the deposition of lime (locally called 'marl'), from the water, by the action of light and vegetal growth, may be studied to advantage. The water is of crystal clearness, and objects on the bottom, under 10 or 15 feet of water, may be distinctly seen. Mussels (*Unionidæ*) are very abundant, and the posterior part of the shells, through which the breathing tubes project up into the water, are almost universally built up with a soft, pasty deposit of lime, varying in thickness from a half inch to an inch and a half, giving them the appearance of being much longer than they really are. This coating of lime excludes the light so completely that the epidermis beneath is a pale salmon hue, and without the rays and color markings peculiar to the species in running streams. The broken surfaces of stones, bits of wood, which, from partial decay, have sunk to the bottom, and the dead stalks of grass and weeds, are all coated with a film of lime. This incrustation appears to accumulate more rapidly in shallow water, where the sun's rays heat it more quickly and to a higher temperature than in deeper portions of the lake.

"A bottle of water was taken from this lake and sent to the laboratory at Indianapolis for analysis. It is clear and has a pleasant taste and is neutral to litmus paper. An imperial gallon (10 pounds) contains 10.5 grains of solid mineral matter, composed of

Bi-carbonate of lime	7.00	grains.
Iron, alumina and silica	2.10	grains.
Magnesia and undetermined	1.40	grains.
Total	10.50	

"It contains no more mineral matter than is commonly present in river water and is not only a potable water in a most eminent degree, and may be drawn from the bottom with a temperature of 50 degrees, which is refreshingly cool without the addition of ice, but is likewise well suited for laundry purposes and for those branches of manufactures which require large quantities of water, such as the manufacture of fine writing paper, printing paper, etc."*

* 7th Ann. Rep. Geol. Surv. of Ind., 1875, pp. 490 and 40.

GAGE AND LIME LAKES.

WORKABLE DEPOSIT.

GAGE LAKE.

Lake Gage lies a short distance northeast of Crooked Lake, with which it is connected by Concord Creek. It occupies a part of section 35 (38 north, 12 east) and section 2 (37 north, 12 east), its eastern shore being about eight miles west of the Fort Wayne Branch of the L. S. & M. S. Railway.

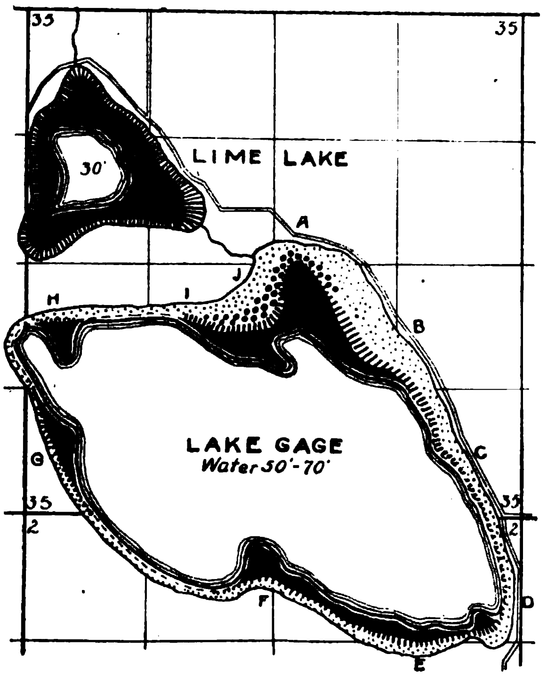


Fig. 8. Map of Gage and Lime Lakes, Steuben County, Ind.

This lake is heart-shaped and quite regular in outline. It has an area of about 350 acres and a diameter of one mile by three-quarters of a mile. The lake occupies a single deep and regular basin with a depth through the center of 50 to 70 feet. The area of shallow water is usually broad, being especially so at the north near the outlet. The general shape and position of the line of six foot water is shown on the map.

The lake ranks among the prettiest in the county, being clear and clean without adjoining marsh or much aquatic vegetation. On the east, hills of gravel rise 25 to 40 feet above the water. The other

shores are less in height, are composed mainly of sand or gravel, and are less regular in outline. There is evidence that the lake is now higher than at some past time.

Marl.—The largest deposit of marl found was at (A). Going south from the shore the marl sets in about 50 feet out in about two feet of water. At 150 feet out the water is three feet deep and marl 10 feet in thickness. At twice that distance the water is four feet deep and marl beyond reach of 16 foot drill. The six foot water line is here nearly 1,000 feet out. Just west of this and 200 feet from shore the marl is only three feet deep in five feet of water. Going from (A) to (B) the belt lacking marl broadens from less than 50 feet to over 200, there being no marl at (B) in four feet or less of water. The line of six-foot water there becomes a belt 400 feet or more wide with the marl four feet deep on the inside and 10 feet or over on the outside. From (B) to (D) the belt of shallow water is narrow, usually not over 100 feet, but getting gradually deeper. There is no marl close to shore, and at only one point was it found in four feet of water. In seven feet of water the marl is usually over nine feet thick. From (E) to (F) the belt of shallow water is irregular but broad, extending out 400 or 500 feet from shore. Except in three feet or less of water, the marl was everywhere below reach of 16-foot drill. From (F) to (I) the shallow water is very narrow, except at (G) and (H). In places at 15 feet from shore in one or two feet of water no marl was found, while at 30 feet out in four feet of water the marl was over 12 feet thick. The marl is deep on the two points mentioned.

In appearance the marl of this lake was of a light dove color and unusually smooth and even. There is little doubt but that it underlies three-fourths of the water area of the lake.

LIME LAKE.

Lime Lake lies just northwest of Lake Gage in section 35. It is a small lake of about 50 acres and is said to be about 30 feet deep in the center. There is a broad bench of shallow water all around the lake, and its shores are low.

Marl.—Except close to shore all the tests made failed to reach the bottom of marl with the 16-foot drill. The deposit of shallow water marl in the two lakes is amply sufficient to justify the erection of a good-sized cement factory; the deficiency in acreage being counterbalanced by the greater average depth. The distance of transportation facilities is, at present, the greatest drawback, and deposits more favorably situated will doubtless be sooner developed.

FOX LAKE.

Not a Workable Deposit.

Fox Lake lies a mile or less southwest of Angola in sections 27, 33 and 34 (37 north, 13 east), Pleasant Township. It is only about half a mile from the Fort Wayne Branch of the L. S. & M. S. Railway. The lake is three-quarters of a mile long by half a mile broad, with an area of about 150 acres. A long, low point from the north, near the west end, shuts off a small bay.

The deep water of the lake has a very uniform depth of more than 40 feet, with a maximum of 60 feet. The water is clear and cold, with clean shores and no marsh except at one point near the west end. A long point of shallow water extends out from (B) on the northeast shore of the lake. Along the part of the shore in sec-

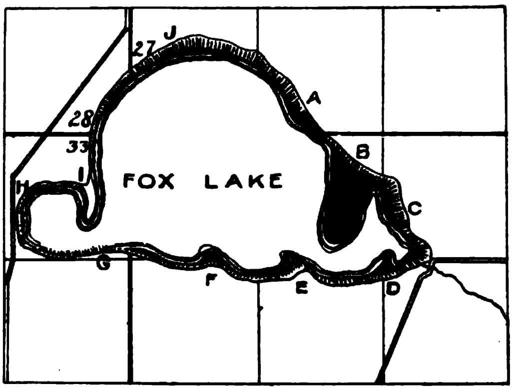


Fig. 9. Map of Fox Lake, Steuben County, Ind.

tions 28 and 33 the shallow water belt is narrow. Around the rest of the lake it is broader and more variable, there being several projecting submerged points on the south side. The shores are high and abrupt all around this lake except near the outlet, which flows southeasterly into Pigeon Creek.

Marl.—At (A) the marl is eight feet thick in four feet of water, and more than 10 feet thick in seven feet or over of water. Over the broad shallow bar running out from (B) the water is from one to four feet deep and the marl from nine feet to over 16 feet in thickness. At the eastern end of the lake the marl does not set in until the water reaches a depth of between one and two feet. In two feet of water the marl showed a depth of eight feet and in two and one-half feet of water, 75 feet from shore, was more than 14 feet. From (D)

to (F) are several points on which the marl was over 16 feet thick except at (E) where the marl was found to be shallow on the crest of the point. From (G) to (I) the six-foot water line runs from 25 to 50 feet from shore, with marl to below drill at most points, but shallower at (G). There the marl was one foot thick at the shore and eight feet thick in seven feet of water. Around the long point, beneath two feet of water, the marl ran over 14 feet thick. At the north side of the lake the shallow water is broader, three feet of water at 200 feet from shore showing 11 feet of marl.

While the lake is largely underlain with marl, the acreage is not deemed sufficient to justify the outlay of capital for a cement factory, especially as much of the marl is at present beneath deep water.

PLEASANT AND LONG LAKES.

Not a Workable Deposit.

PLEASANT LAKE.

This lake is situated near the town of the same name, on the Fort Wayne Branch of the L. S. & M. S. Railway. It is in sections 14, 15, 22 and 23 (36 north, 13 east), Steuben Township. The lake is half a mile long by a quarter of a mile wide, with an area of about 75 acres. The basin is symmetrical, with a depth of 30 feet close to shore and 40 to 50 feet through the middle. The belt of shallow water, as a rule, is very narrow. The banks rise sharply all around, except at the outlet, to a height of 10 to 20 feet.

Marl.—In the northwest corner of the lake the drill found only muck, that in two feet of water being three feet deep, but running out before a depth of 13 feet of water is reached. Going south along the west shore the marl sets in and increases in depth. At (B) the marl is four feet deep in one foot of water and six feet deep in two feet of water. At (C) it is 10 feet deep in three feet of water, and in deeper water quickly extends to below 16 feet. Continuing toward (D) the marl becomes thin until at that point it is not over three feet thick in any depth of water up to 16 feet. At (E) only muck was found. The largest body of marl occurs in the embayment at (F), where drillings in from two to four feet of water failed to reach the bottom of the marl, four-foot water extending about 150 feet from shore. Toward (G) the marl is still over 10 feet thick on the six-foot water line, 50 feet from shore. At (H) four feet of water shows from two to 10 feet of marl. At (I) the marl is nine feet deep on the six-foot water line, 30 feet from shore, and just on the

edge of deep water. Toward (K) the marl becomes shallow, being four feet deep in three feet of water at (J), 25 feet from shore; but at (K) only reaches a thickness of one foot in nine feet of water. At (L) four feet of mucky marl was found in seven feet of water.

The shallow water marl deposit in the lake is, from the tests, seen to be meager in size, while that supposed to be in deep water is not promising.

LONG LAKE.

Long Lake lies just northwest of Pleasant Lake village, close to the L. S. & M. S. Railway. It is in sections 15 and 16 (36 north, 13 east). The lake is a little over one mile long by one-quarter of a mile wide, much resembling in shape a willow leaf, and has an area of about 150 acres. In depth Long Lake varies from 25 to 40 feet. Except at the east end the belt of shallow water is rather narrow. The land around the lake is inclined to be marshy, and an extensive marsh stretches east and south from the eastern end of the water area. The water of the lake is of the rich amber color characteristic of Pigeon Creek, which flows through the lake, entering at a point west of the middle on the north side and flowing out at the western extremity.

MARL.—At the east end of the lake the bottom is of muck to beyond reach of pole at all depths of water from one to six feet. From (B) to (D) marl sets in, and while not far from (B) it reaches a thickness of 12 feet in two feet of water, it grows shallower to the west, finally running out between (D) and (E), where the bottom is of sand at all depths up to 16 feet. On the south side of the lake, marl shows from (F) to (H). It is of fair depth, the marl in three to four feet of water running from eight to 12 feet in thickness, while near (H) it was over 12 feet in four feet of water. The shallow water varies in width from 75 or less to 150 feet. A little east of (H) sandy bottom sets in and is found at all depths between (H) and (J), where the marsh begins.

The tests show that the area of shallow water marl in Long Lake is less than in Pretty Lake, and we are therefore led to believe that no workable deposit of marl occurs in the two lakes, even if that below deep water was largely available.

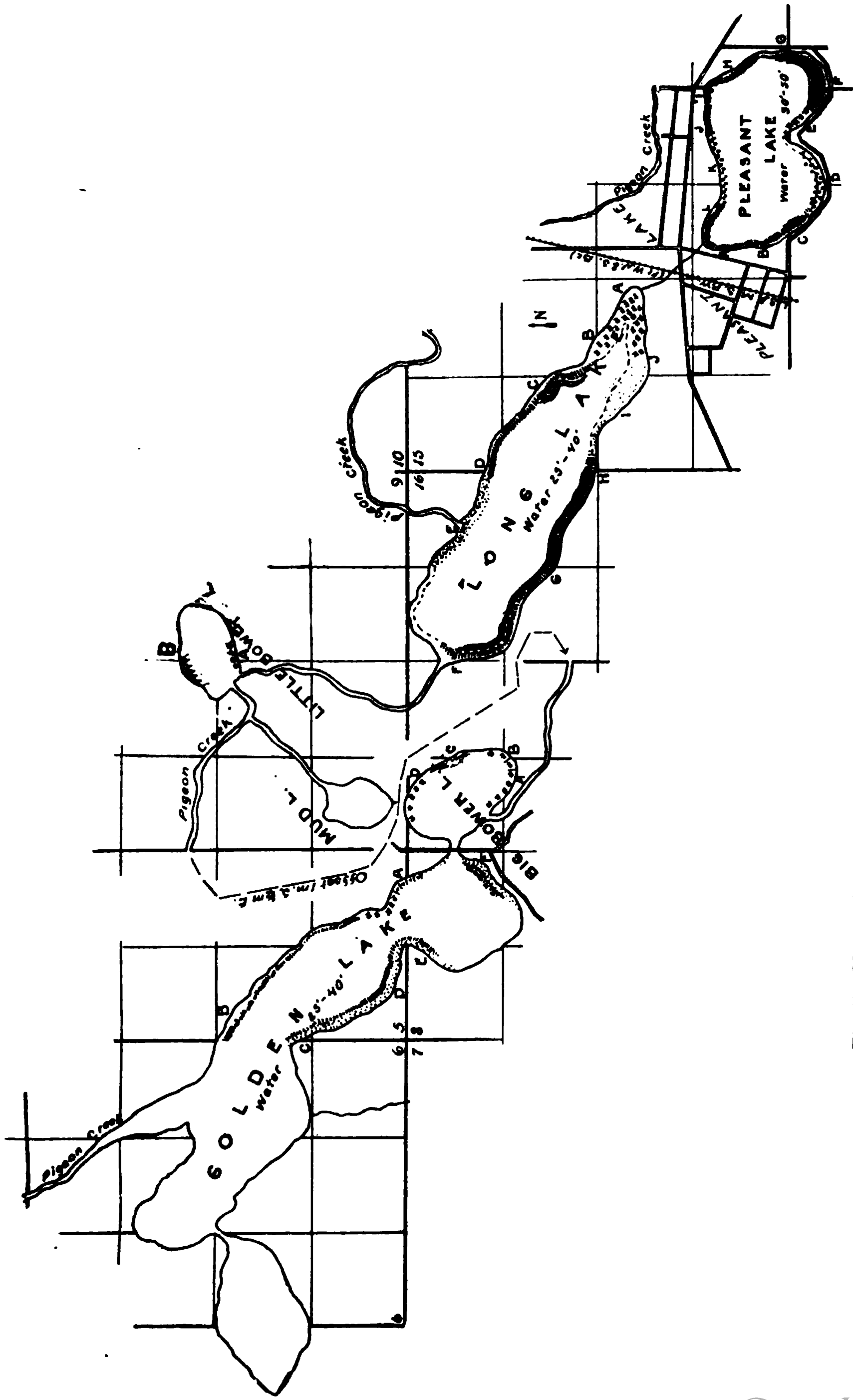


Fig. 10. Map of Golden, Bower, Long and Pleasant Lakes, Steuben County, Ind.

BOWER AND GOLDEN LAKES.

Not a Workable Deposit.

BIG AND LITTLE BOWER LAKES.

These are two small lakes or kettle holes filled with water, through which Pigeon Creek runs on its way from Long Lake to Golden Lake. The deep water of each sets in close to shore. Only muck was found on the south side of Little Bower. On the north side a little marl was found under six feet of muck. In Big Bower 13 feet of mucky marl was found in two feet of water at (C) and a little marl under 15 feet of muck at (B); otherwise only muck was found.

GOLDEN LAKE.

Golden Lake lies just northwest of Big Bower Lake, in sections 5, 6 and 8 (36 north, 13 east). It has a length of about one and one-half miles and a width of one-quarter of a mile. In shape it is a counterpart of Long Lake with a more irregular shore line. Its depth varies from 25 to 40 feet.

Marl.—On the north side a little marl was found, usually under several feet of muck. On the south side the bottom seems to be hard out to where the water is three or four feet deep. Then the marl sets in, but it is mucky and shallow. At (C) the marl is only three feet deep in seven feet of water. At (D) it is 11 feet deep in four feet of water. At (E) it has become shallow again and is approximately as at (C). At (F) the marl is five feet deep in four feet of water and seven feet deep in seven feet of water, but with muck on top. In water over 10 feet the bottom of marl could not be reached on the north side, but it was generally quite mucky. While there is doubtless a large area of deep water marl in the lake, it can never be used for cement making on account of its quality.

SILVER LAKE.

Workable Deposit.

Silver Lake lies four miles west of Angola, in sections 29, 30, 31 and 32 (37 north, 13 east), Pleasant Township. While only two and one-half miles in a straight line from the Fort Wayne Branch of the L. S. & M. S. Railway, it did not appear possible for a switch to be built via Fox Lake, but it must, instead, go from Pleasant Lake down Pigeon Creek by the side of Golden and Hog Back Lakes. Silver Lake is oval in shape, one mile long by three-quarters of a mile

wide and with an area of about 300 acres. The marl deposit in this lake and adjacent to it extends up under a large marshy area to the north (probably 100 acres or more), including Mud Lake and a small lake in section 19.

The lake is rather shallow, the greatest depth being only 25 to 30 feet, while probably half of its area has a depth of six feet or less. Most of the shallow water is in the northeast part. Three island-like shoals, noted on the map, come nearly to the surface of the water.

The outlet starts from a little basin at (F) which is almost shut off from the main lake, and flows into Hog Back Lake, an enlargement

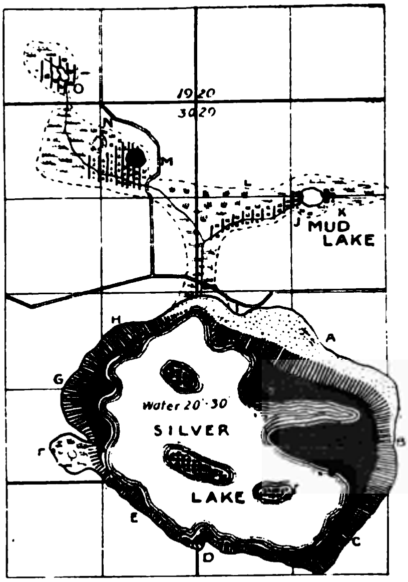


Fig. 11. Map of Silver Lake, Steuben County, Ind.

of Pigeon Creek. The shape of the marsh to the north is shown on the map. There is a small but high knoll in the arm of the marsh near (N).

The hills on the east side of the lake, though rising gently, attain a considerable height. The marsh land is shut in by rather steep hills. The shores west of the lake are not so high.

Marl.—Though small, this lake contains one of the best deposits of marl in Steuben County. It takes its name from the silvery reflection from the marl just below the water surface. The water has been lowered several feet, rendering the marl more noticeable.

In the northeast part of the lake, there is no marl near shore, but by the time two feet of water is reached the marl is four feet deep, and over 12 feet before four feet of water is reached. There are two extensive areas extending out from (A) and (B) with ten feet of water between them, also underlain with marl to below 16 feet.

Around the south side of the lake, the shallow water belt is narrow and the bottom of the marl was reached at most points at depths of from nine to 11 feet in two feet of water. On the west side the shallow water belt is broader, and except toward the northwest, has much marl over 14 feet deep in two feet of water.

Over most of the marsh to the north, as far as tested, the muck is too deep to permit the working of the marl. At (M), however, the marl comes to the surface over a small area and is over 16 feet deep. It was formerly worked here for lime, being cut out in blocks with a spade.

Just south of the knoll at (N) the muck is three feet or more thick, with seven feet of marl beneath. From (M) to (N) the depth of the muck increases until at (N) it is seven feet in thickness. Near the small pond at (O) the muck is seven feet deep, with marl below to over 16 feet. In the eastern arm of the marsh the least depth of muck was found just west of Mud Lake, where it was three feet with 10 feet of marl below. East of Mud Lake the muck is four feet or more thick, with marl below to over 16 feet.

An analysis of marl from this lake made by Dr. C. R. Dryer, showed its constituents to be as follows:*

Calcium carbonate	84.00
Magnesium carbonate	6.46
Ferrous carbonate	1.34
Silica and silicates	4.52
Organic matter	3.68
	100.00

Judging from the analysis, the sample taken by Dr. Dryer must have been secured from near the surface. From the general appearance of the marl we should judge that an average sample, taken from a dozen or more localities, some distance below the surface, would show a higher percentage of carbonate of lime and less magnesia and organic matter.

From the location cited, we judge that the sample of marl, whose analysis is given in the Report of the Indiana Geological Survey for 1878, p. 87, was taken from the western side of Silver Lake. Prof.

*17th Ann. Rep. Ind. Geol. Surv., 1891, p. 126.

Cox's statement regarding it is as follows: "The composition of a sample (marl) taken from the farm of G. W. Slocum, on section 30, T. 37, R. 13, in Steuben County, Indiana, is:

Moisture expelled at 212 degrees	8.00
Insoluble silicates	0.30
Alumina with traces of iron	1.50
Lime	45.36
Magnesia	3.42
Carbonic acid	41.50
Sulphuric acid	0.10
Phosphoric acid	0.38
	100.56

FISH LAKE.*

NOT A WORKABLE DEPOSIT.

Fish Lake lies immediately north of the town of Hamilton, in sections 21, 22, 27, 28 and 33 (36 north, 14 east), Otsego Township. It is but one-half mile north of the Chicago Division of the Wabash Railway. The lake is nearly two miles long from north to south and just one and one-half miles wide from east to west. It is very irregular in shape, comprising a main body to the north with arms extending to the east and west, known as the Devil's Neck and Muskrat Bay, and to the south narrowing down to what is known as the Mill-pond, with a considerable body to the southwest almost shut off by South Island. The area, according to Col. J. M. Wilson, is 740 acres. The lake was formerly in three different bodies of water. In 1837 the outlet was filled in and the surface of the lake was thus raised nine feet, which united the three lakes into one body of water. The water power of this lake is utilized for milling purposes, and is at present controlled by the Fort Wayne Water Power Company. It has several islands, the largest, South Island, containing 13 acres, the others less than one acre each. The large island is covered with a growth of small oak.

The large basin forming the north part of the lake has a maximum depth of 68 feet, and a temperature in July of 70 to 75 degrees. In the narrow part of the lake in its middle the water is from two to 62 feet deep with an average of 40 feet. There is a small island a little northeast from the mouth of Muskrat Bay which is probably the southern end of a long bar. Northeast of this island, near the middle of the main lake, the depth was only 30 feet and the tem-

*This lake was visited in July, 1893, by Mr. Blatchley, while working for the U. S. Fish Commission, and again by Dr. Ashley in November, 1899. The most of the data relative to depth and temperature, and the list of fishes, were secured on the first visit.

perature of the water 57 degrees. The low temperature of the water at this point would indicate the presence of strong bottom springs.

A bay (Devil's Neck) extends from the northeast side of the main lake in a southeast direction. It has a length of three-quarters of a mile, and along its middle line a depth of 40 feet and a temperature of 67 degrees. Toward the shores the water gets shallower, with a corresponding increase in temperature. In 12-foot water the temperature was 70 degrees. The narrow channel leading to the Mill-

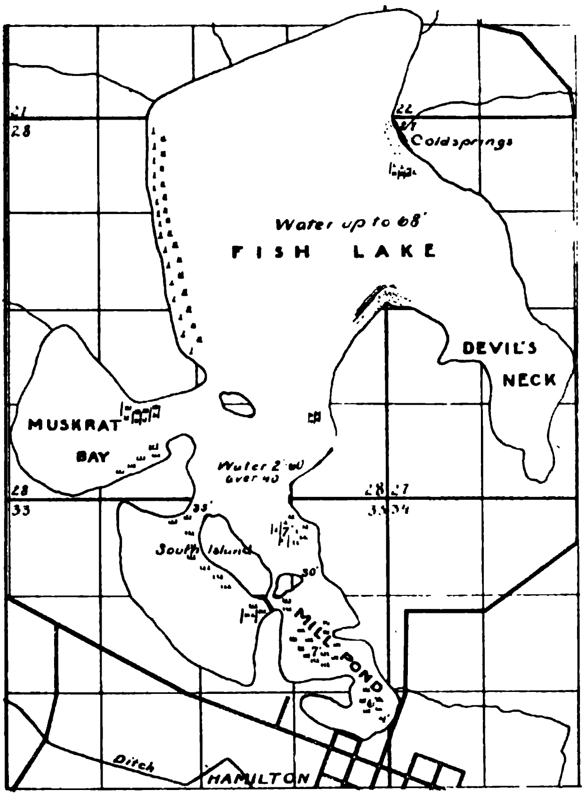


Fig. 12. Map of Fish Lake, Steuben County, Indiana.

pond is, in places, 30 feet deep, though only seven feet of water was found well out in the channel a little north of this. Tests in the Mill-pond showed a depth of water from four to nine feet, and the temperature of the water at this depth was 73 to 74 degrees. The temperature of the water immediately below the surface in all parts of Fish Lake was 78 degrees.

The shores of the main lake on its northwest and east sides are gravelly, with clean bottom, and the banks at either place are rather

abrupt, with a height of from 10 to 20 feet, and are covered with woods. The remainder of the shores of the lake are more or less swampy, with several large patches of peat or muck, except along the large island, where the bottom is rather clean and solid. On the east side of the main lake are several strong springs. The water of these springs is charged with iron sulphate, and has a temperature of 49 degrees F.

Fish Lake receives its waters from several ditch-like tributaries, but chiefly from the springs along its shores and bottom. It empties its waters from the lower end of the Mill-pond into Fish Creek, of which it is the source, the latter stream flowing into the St. Joseph of the Maumee. The land around the lake is very uneven, being full of kettle holes and other depressions between conical and dome-shaped drift hills.

The water in Fish Lake is clear and well stocked with native game and food fish. The ringed perch (*Perca flavescens*), the blue gill (*Lepomis pallidus*), the common sunfish (*Lepomis gibbosus*), and the large-mouthed black bass (*Micropterus salmoides*) are among the most common food fishes. The following is a complete list of the fishes taken in the lake on July 19 and 20, 1893, by the party connected with the U. S. Fish Commission:

List of Fishes in Fish Lake.

1. *Lepisosteus osseus* (L.). Long-nosed Gar-pike.
2. *Ameiurus nebulosus* (Le S.). Bullhead.
3. *Catostomus nigricans* Le S. Hog Sucker.
4. *Moxostoma macrolepidotum duquesnei* (Le S.). Common Redhorse.
5. *Pimephales notatus* (Raf.). Blunt nosed Minnow.
6. *Notropis heterodon* (Cope). Northern Notropis.
7. *Notropis whipplei* (Girard). Silver-fin.
8. *Semotilus atromaculatus* (Mitchill). Creek Chub.
9. *Zygonectes notatus* (Raf.). Top Minnow.
10. *Lucius vermiculatus* (Le S.). Grass Pike.
11. *Labidesthes sicculus* Cope. Skipjack.
12. *Pomoxis sparoides* (Lacépède). Calico Bass.
13. *Chænobryttus gulosus* (Cuv. and Val.). Warmouth.
14. *Lepomis pallidus* (Mitchill). Bluegill.
15. *Lepomis gibbosus* (L.). Common Sunfish.
16. *Micropterus salmoides* (Lacépède). Large-mouthed Black Bass.
17. *Etheostoma nigrum* Raf. Johnny Darter.
18. *Etheostoma eos* (Jor. and Cope.). Sunrise Darter.
19. *Etheostoma microperca* Jor. and Gil. Least Darter.
20. *Perca flavescens* (Mitchill). Yellow Perch.

The Mill-pond and western side of Fish Lake are in places largely filled up with vegetable growth, the pond being covered with the white water lily *Castalia odorata* (Dryand). Dr. Dryer, who made careful observations in the summer season, reports that in the bays of the west shore the outer zone of vegetation begins at a depth of 10 feet with a band of Chara, Potamogeton and eel grass, *Vallisneria spiralis;* the latter peculiar to this lake. At a depth of five feet the white pond lilies, *Nymphæa*, flourish, the spatterdock or yellow lily, *Nuphar*, being scarce. At a depth of three feet rushes, smartweed and cat-tails form a floating margin too thick to push a boat through. Above water level, on the solid mass of peat, a great variety of plants flourish, among which, besides grasses, small sedges and ferns, are the water hoarhound, *Lycopus europæus*, the clearweed, *Pilea pumila*, the shrubby cinquefoil, *Potentilla fruticosa*, the willow herbs, *Epilobium coloratum* and *palustre*, the arrow-leaf, *Sagittaria variabilis*, the meadow cone-flower, *Rudbeckia hirta*, and the jewel-weed, *Impatiens fulva*, the latter covered with tangled orange skeins of the dodder, *Cuscata gronovii*. Besides these are also found the bedstraw, *Galium asprellum*, the marsh bellflower, *Campanula aparinoides*, the blazing star, *Liatris spicata*, the cardinal flower, *Lobelia cardinalis*, the swamp milkweed, *Asclepias incarnata* and the skull cap, *Scutellaria galericulata*, all conspicuous in August. In many places the strictly aquatic plants are absent, and the peat bed rises with a clean cut edge two feet above the water.

"The large area of Fish Lake, furnishing a broad expanse of water visible at one sweep of the eye, its irregular outline and prominent islands, its bold shores and encircling hills, and the beauty and profusion of its aquatic vegetation, form a combination of characters which render this lake one of the most interesting and attractive in the State. The village of Hamilton, at its south end, is clean and quiet, and furnishes such accommodations to the summer visitor as can not fail to make his stay enjoyable."*

MARL.—On account of the recent elevation of the water surface of this lake no marl need be looked for in less than seven or eight feet of water. Most of the drillings made in seven feet or less of water showed muck to below 16 feet. A little marl was found beneath six to eight feet of muck at the following localities: Near the south end of South Island; east of South Island; on the north side of the entrance to Muskrat Bay; just off from Cold Springs, and on the east shore opposite the mouth of Muskrat Bay. Marl without overlying muck was found around the point south of the mouth of

*17th Ann. Rep. Ind. Geol. Surv., 1891, p. 129.

Devil's Neck. The marl does not set in until seven feet of water is reached and then quickly deepens to beyond 16 feet. It was of a dark gray color. In the center of the channel east of South Island at least six feet of light brown marl was passed through beneath three feet of muck. On account of the conditions found to exist, no attempt was made to make a thorough test for the marl in the lake, as it is practically all beneath water too deep to allow the deposit to be worked.

LAGRANGE COUNTY.

REFERENCES.—

1859.—Richard Owen, Rep. of a Geol. Reconn. of Indiana, p. 198.

1873.—G. M. Levette, Fifth Ann. Rep. Geol. Surv. of Indiana, p. 444.

1893.—Dr. C. R. Dryer, Eighteenth Ann. Rep. Dept. Geol. & Nat. Resources of Indiana, p. 72.

1899.—Frank Leverett, Water Supply and Irrig. Papers, of the U. S. Geol. Survey, No. 21, p. 25.

On the northern border of the State and in the second tier of counties from its eastern boundary is Lagrange, which contains one of the most fertile sections of northern Indiana. It has an area of 393 square miles and lies between Elkhart and Steuben counties and north of Noble County.

The county is well supplied with railways. The Grand Rapids & Indiana crosses it from north to south near the center, passing through Lima, Lagrange and Wolcottville. The Chicago Division of the Wabash runs along its southern border, crossing the G. R. & I. at Wolcottville. The Goshen Branch of the Lake Shore & Michigan Southern crosses the northwestern corner, passing through Shipshewana and meeting the G. R. & I. at Sturgis, Michigan, six miles north of Lima. The elevation in feet above tide of the stations on the G. R. & I. Railway is as follows: Lagrange, 925; Lima, 886; Valentine, 967; Wolcottville, 949.

The elevation of the county is between 897 and 1,027 feet above tide, and the whole area is covered with drift from 100 to 200 feet or more in thickness, the bottom of which has rarely if ever been reached. "The general surface slopes gently to the north, except the lake region of Johnson Township, which is drained southward into the Elkhart River, the crest of the divide being near Valentine. It lies entirely upon the Saginaw side of the Saginaw-Erie interlobate moraine of Chamberlain, and contains no Erie drift, except, possibly,

at the southeast corner. It is crossed by two terminal moraines of the Saginaw glacier, so that about one-half of the county presents a topography of a distinctly morainic character, but its outlines and distribution are so irregular as almost to defy description in words."*

The lakes of Lagrange County are not so numerous as those in Steuben County on the east or Noble on the south. About 40 occur which have been deemed worthy of name on the maps of the county heretofore issued. The total area of water in the county is about 4,000 acres, 1,500 of which are in Johnson Township. Twenty-two of the lakes were visited during the progress of the present survey and are briefly described on the pages which follow. Nine deposits of marl of workable size, i. e., containing an area of 160 or more acres and averaging 10 feet or more in thickness, were found in the county. These are either in single lakes or in groups of lakes the members of which are in adjoining sections. Of the nine, four are easily available for cement making under present conditions. The other five are, for the most part, found beneath water 10 feet or more in depth, and are therefore not available until appliances are invented for readily securing the marl from beneath such depth of water.

SHIPSHEWANA LAKE.

Workable Deposit; Second Class.

The eastern edge of this lake is about three-quarters of a mile west of the town of the same name. The lake lies in sections 4 and 9 (37 north, 8 east), Newbury Township. The Goshen and Michigan Branch of the Lake Shore & Michigan Southern Railway passes within one-quarter of a mile of its southeastern corner. The lake is about three-quarters of a mile in length from southeast to northwest by one-half mile in greatest width, and has a water area of 200 or more acres. The western half of the north shore and the west shore are bordered by extensive muck meadows. The east half of the north shore and the east side have wooded hills sloping gently back to a height of 30 to 50 feet. On the east these extend to the water's edge and furnish fine sites, as yet unutilized, for cottages. On the northeast the hills are separated from the lake by a strip of muck covered marsh five to 20 rods in width. On the south shore a marsh 20 rods in width and covered with wire-grass and other vegetation lies between the water's edge and the higher wooded slopes to the southward.

* Dryer, loc. cit., p. 73.

The lake is everywhere shallow, the greatest depth found being 14 feet, and the average depth not over eight feet, with probably half of its area less than six feet. Its waters contain much vegetation. On the east and north sides the principal growth is the giant rush, *Scirpus lacustris* L., which forms large beds, extending out into five and seven-foot water. On the west side the stems and leaves of spatterdock, *Nymphæa advena* Sol., and of the white water lily, *Castalia odorata* (Dryand), cover large areas of the water surface and by their decay are gradually replacing the water with muck. Several species of pondweed (*Potamogeton*) grow in all parts of the lake, their flowering parts reaching above the surface of eight to 10 feet of water, while their roots are buried in the muck and marl at the bottom. The water-shield, *Brasenia purpurea* (Michx.), with its curious flowers and floating peltate leaf is also a very common plant in most parts of the lake, while the ditch moss, *Philotria canadensis* (Michx.), covers a large portion of the lake's bottom. So much aquatic vegetation doubtless aids much in separating the marl-forming material from the water, but at the same time, the decay of the plants adds an undue percentage of organic matter to the slowly depositing marl and renders it dark in color.

MARL.—All along the east side the marl sets in about 50 feet from shore, the intervening strip of bottom being sand. In four foot water the marl was 10 feet thick, underlain with gravel. In all water over four feet, bottom of marl could not be reached with an 18-foot auger. Along the north side the marl was found closer to shore but was usually covered with a foot or less of muck out to 75 or 100 feet, where the muck disappeared. The tests nowhere found bottom of marl, except at a point 20 rods southwest of the northeast corner of the lake where, in three feet of water, the marl was nine feet thick, with gravel beneath. Twenty rods south of this point and the same distance from the east shore it was 15+ feet in three feet of water. A number of bores diagonally across the lake to the southwest corner gave 14+ feet of marl in four feet of water to within 10 rods of shore. Here, one-third the distance east from the west end of the lake, the drill touched gravel in four feet of water, showing the marl to be just 14 feet thick, the upper third dark, the lower portion of good quality. On the west side a bed of thick muck extends out 50 yards from shore, where it is gradually replaced by marl 14+ feet in five feet of water.

The marsh on the south shore showed muck four to six feet with gravel beneath. In the meadow on the north and west shores the muck was 18+ feet deep, with no indications of marl. Along the

south shore to the eastward the marl was everywhere six to 10 feet thick in three feet of water, 10 rods from shore. In greater depth of water and farther from shore, bottom of marl was nowhere found.

From the tests made it is safe to say that 160 acres of the lake are underlain with marl which will average 10 feet or more in thickness. The upper third of the marl is in many places darker in color than the remainder. This is doubtless due to the larger percentage of organic matter derived from the decay of recent aquatic vegetation.

TWIN LAKES.

Large Deposit, Mostly Under Deep Water.

Twin Lakes are located two miles west of Lima, in sections 23, 26 and 27 (38 north, 9 east), Lima Township. They are about one-third of a mile east of Twin Lake Station on the Goshen & Michigan Branch of the Michigan Southern Railway, and two miles west of the Grand Rapids & Indiana Railway.

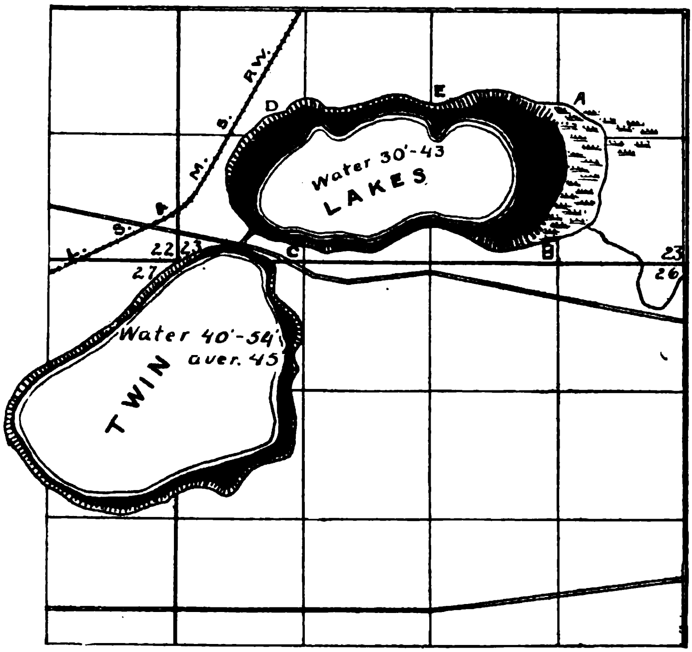


Fig. 13. Map of Twin Lakes, Lagrange County, Ind.

The upper lake is shaped somewhat like the bottom of a shoe and is about three-quarters of a mile long by one-fourth of a mile wide, with an area of nearly 160 acres. The lower lake is somewhat smaller and is roughly pear-shaped, with the narrow end to the west.

North Twin Lake has a depth of from 30 to 43 feet, with rather broad areas of shallow water in the east end and northwest corner, and much vegetation in the southwest corner. This, by its decay, is forming muck, thus gradually decreasing the water area of the lake from that direction. The banks of gravel and clay rise rather abruptly from 10 to 25 feet. The two lakes are not over 20 rods apart, with a wagon road running between them. The presence of marl and fragments of shells beneath the sand in the lowest part of the dividing ridge indicate that in a time not very remote the two lakes were one continuous sheet of water.

The bottom of South Twin Lake shelves off very abruptly along most of the north and west shores, 15 to 20 foot water being found in most places 75 feet from shore. Hills of drift rise abruptly 30 to 50 feet from the water's edge on the east and north shores, while at the west end is a muck meadow. On the south shore a strip of marsh separates the hills and water. The shallow area of the latter extends out 50 to 250 feet on the east and south, many rushes growing therein.

A row of soundings, taken 20 oar-strokes apart, from north to south along the eastern edge of the western third, showed the depth to be respectively 22, 32, 34, 36, 48, 40, 32 and 20 feet. A little east of the center, soundings from south to north gave 24, 36, 42, 48, 54, 46, 40 and 32 feet, 54 feet being the maximum depth found. The water of this lake is in hue a clear greenish blue and wholly free from visible vegetable organisms. In this respect it differs much from that of Shipshewana and other lakes in the region hereabouts. But little muck is found in the lake and that only along the shore of the meadow at the west end.

Marl.—The north lake has a large body of marl at the east end. The water here is very shallow and the marl everywhere tested extended to below 16 feet. There are also several acres of marsh at this end of the lake. Along the south side of the lake from (B) to (C) the shallow water belt is narrow, probably not averaging over 50 feet, though the marl shows a good depth except close to shore. Around the west end there is also considerable shallow water with deep marl. Along the north side it was estimated that the shallow water had an average width of 150 feet, with deep marl except close to shore. It was estimated that there are nearly 50 acres of shallow water in this lake, most of which was underlain by marl to below 16 feet. In appearance the marl seemed to be of very fine quality, being soft and smooth, and of a dove color.

In the south lake on the north side, marl of good quality was found all along the outer edge of the narrow shallow water area. In thickness it runs from eight to 14+ feet in four feet of water, thinning out to one foot at edge of shore. Numerous tests showed that the wider shallow water areas on the east and south sides are likewise underlain with a deposit 12+ feet in thickness in three to six feet of water. There is no doubt but that the marl exists beneath the entire deep water area of the lake. The quality is of the best, being, if anything, superior to that in the north lake. Altogether, the marl deposits of the two lakes are sufficient to furnish material for an unlimited number of years to any cement factory which might be erected, provided some means were devised for securing that beneath the deep water after the 75 or more acres in shallow water had become exhausted.

CEDAR, GRASS AND LIBEY LAKES, AND ADJOINING MARSHES.

Workable Deposit.

CEDAR LAKE.

Cedar Lake lies about three miles northeast of Lima in sections 21 and 22 (38 north, 10 east). It is two and a half miles east of the Grand Rapids & Indiana Railway.

This lake is nearly a mile long by one-half a mile or more broad. There is a small, nearly land-locked bay at the south end. The area is about 175 acres.

The lake is shallow, having a maximum depth of 24 feet with an average of not over 18 feet. On the south and east sides the banks rise abruptly 15 to 20 feet. A high point with a narrow neck projects out from the southeast corner. In 1832 this was fortified and called "Fort Donaldson." There is a small island a little north of the old fort.

Marl.—On the east side of the lake the marl is quite limited in amount, usually not setting in until some distance from shore and on the six foot water line running from 10 feet or over near (A) down to a few inches by the time the island is reached, with no marl just north of the island. South of the island the marl is shallow. In the embayment at the south end the marl runs from 10 feet to over 16 feet in depth, but is very mucky. All along the west shore there is a narrow belt where, in from four to six feet of water, the bottom of the marl was not reached at 16 feet. There is little doubt but that the deposit underlies the greater part of the water area, thinning out towards the east shore.

GRASS LAKE AND MARSH.

This lake and adjacent marsh lie just south of Cedar Lake, being partly in the same section, but mainly in section 27.

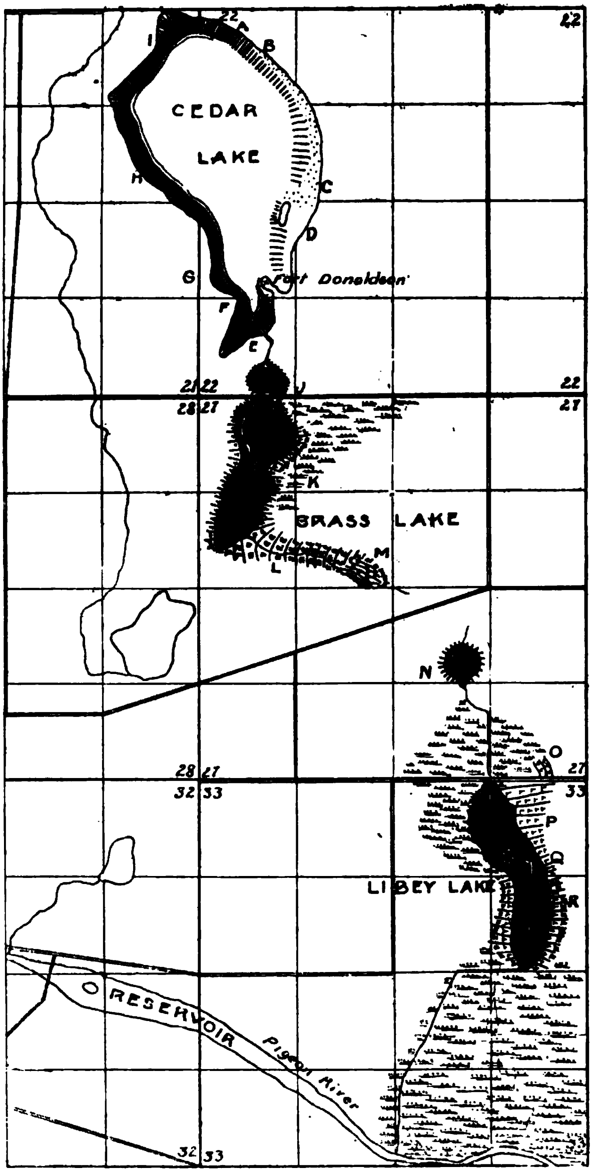


Fig. 14. Map of Cedar, Grass and Libey Lakes, Lagrange County, Ind.

The lake, as far as could be examined, seemed to be very shallow, appearing as though nearly filled up with marl. The marsh on the east side is rather extensive, running eastward from each end of the lake. On the west of the lake the bank is more abrupt.

MARL.—The deposit here covers probably 65 acres or more of exposed marl, 15 acres of which are in section 22. The lake occupies but a part of this area. The marl at all points tested was over 16 feet deep. On the north marsh back from the water it passes under the muck which in a short distance becomes over seven feet deep, or too deep to work.

Tests in the south prong of the marshes to the eastward showed that toward the head of that prong the muck thinned down to two or three feet, with the bottom of the marl not reached at 16 feet. Over how large an area of the marsh such conditions occurred could not be accurately determined.

LIBEY LAKE AND MARSH.

This deposit lies southeast of Grass Lake, in sections 27 and 33, where it occupies part of a considerable marsh. It is estimated that there are about 60 acres of this in section 33, where the marl is bare or covered by less than one foot of muck with marl over 16 feet deep.

The deposit at (N), in the northwest quarter of the southeast quarter of section 27, was estimated to contain 15 acres of deep marl. The thickness of the muck seemed to be irregular outside of the areas mentioned, occasionally, as at (O), being two feet or less thick with over 14 feet of marl underneath, and the next drilling, but a short distance away, perhaps showing six or seven feet of muck, so that it is difficult to say how much of that portion of the marsh overlain with muck contains workable marl. Libey Lake, which formerly covered the entire marsh, has now an area of only about an acre, having been reduced by artificial drainage.

Taking in connection with the 140 acres of marsh and shallow water marl in Grass and Libey lakes the deposit in Cedar Lake, the approximate area of which is unknown, it will be seen that we have here a good workable deposit for a cement factory of large capacity. From the extreme north end of Cedar Lake to the southern extremity of Libey Lake, the distance in a straight line is but little more than two and a half miles, so that with an electric tramway the three de-

posits could be easily worked from one plant, especially if the latter were situated near the center of the territory—say on the margin of Grass Lake.

GRASS AND FISH LAKES.

Workable Deposit.

GRASS LAKE.

This lake is now a dry or semi-dry, level marsh or marl plain. It lies in section 31 (37 north, 11 east), Springfield Township, about eight miles south of east of Lagrange. The lake, recently drained, had an area of about 100 acres. Over this the marl presents a bare surface, resembling in places the alkali plains of the west, more or less overgrown with bulrushes. At no point in this deposit was bottom reached with our 16-foot drill, and it is claimed that tests with long poles show it to have a depth of 30 feet or more over most of the area.

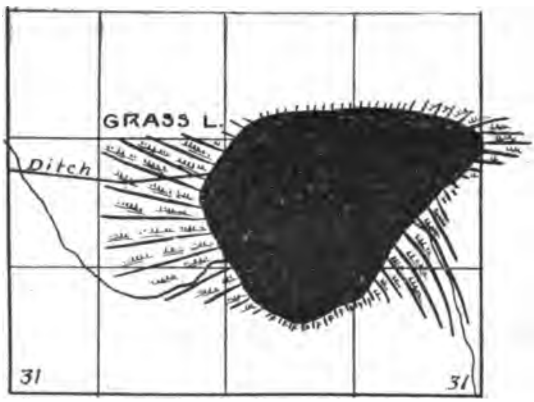


Fig. 15. Map of Grass Lake, Lagrange County, Ind.

This lake area is surrounded by a considerable original marsh area and it is reported that there is fully 100 acres of this that is underlain with deep marl with but little cover, making in all 200 acres, with a thickness of 16 feet or more. The marsh area was not examined or mapped. The area shown on the map is therefore only suggestive of the general position and shape of the marsh. It probably extends much farther west than shown.

This deposit is easily workable and is one of the largest in the county, lacking only railway facilities to make it a very valuable

property. It is now owned by Chicago parties who secured it for a nominal sum, and who are expecting to develop it in the near future.

FISH LAKE.

This lake lies a mile and a half west of Grass Lake which, before draining, emptied into it. It has an area of about 140 acres, a maximum length of nearly three-quarters of a mile and a width of nearly one-third of a mile. At most points around the lake the marl extends back beneath the shore from a few yards to several rods, so that the depth at the water's edge is often from six to 15 feet or over. At most places it is not over 50 feet from the shore to the edge of deep water. Wherever the water is two feet or more deep the marl below reaches a depth of over 16 feet. At (F) the marl is shallower and at (C) the bottom is sandy for a short distance out. At (B) there is a broad bench of marl, amounting to several acres, which is 16+ feet in depth.

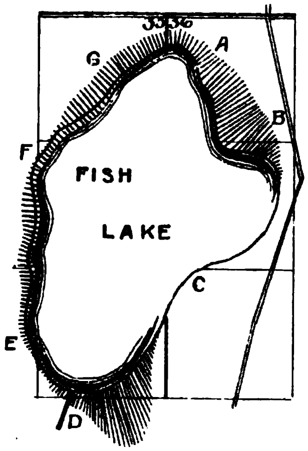


Fig. 16. Map of Fish Lake, Lagrange County, Ind.

It is possible that Fish Lake in itself contains enough marl to furnish material for a cement factory, but at present the greater part is beneath deep water and therefore not available. That portion along shore and beneath shallow water could be readily utilized in connection with the dry deposit at Grass Lake, provided there should be need for additional material.

TURKEY AND LITTLE TURKEY LAKES.

Workable Deposit, Owned and Utilized by the Wabash Portland Cement Company.

These lakes will be considered together, as they are not only close together but are at present owned by the same company and so may commercially be considered as one deposit. They lie in sections 1, 2, 11 and 12 (36 north, 11 east), Lagrange County, and sections 7 and 18 (36 north, 12 east), Steuben County. They were in 1899 connected by a switch, five miles in length, with the Chicago Division of the Wabash Railway at Helmer. The two new towns of Stroh and

Elmira, about one-half a mile apart, have sprung up near the cement works since their establishment. In October, 1900, they contained probably 50 houses.

The lakes have recently been lowered by the digging of a long ditch, materially reducing the size of their water areas, especially that of Little Turkey. The depth of water in Big Turkey Lake is re-

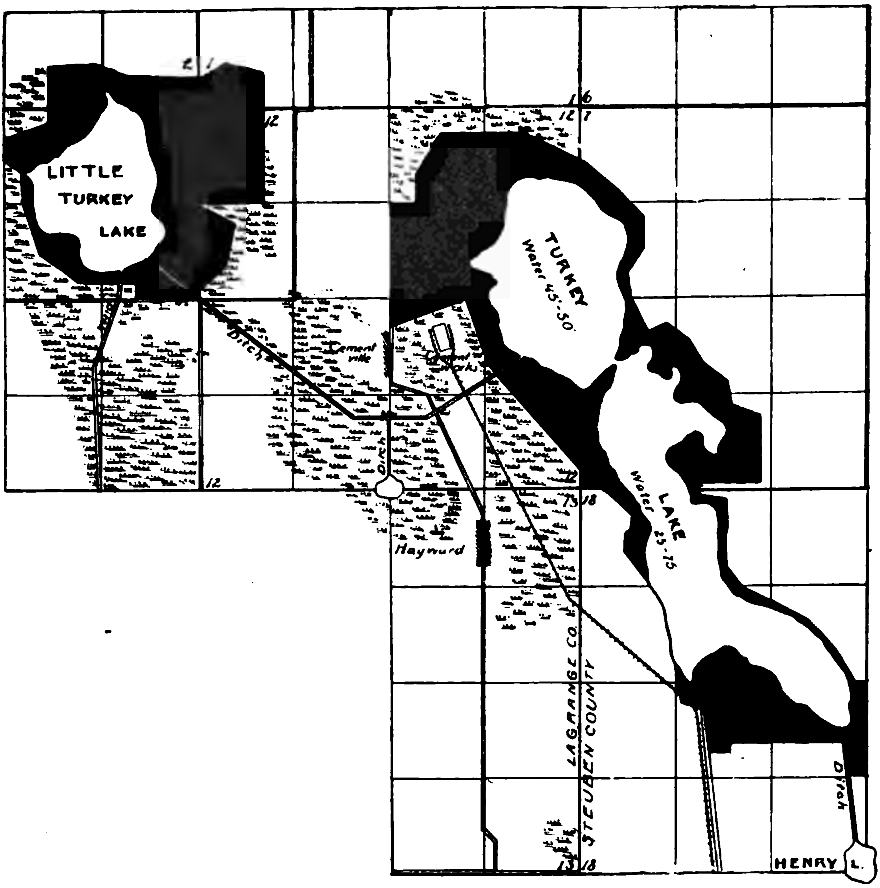


Fig. 17. Map of Turkey Lakes, Lagrange and Steuben Counties, Ind.

ported to be 45 to 50 feet in the northern lobe and 25 to 75 feet in the southern lobe. The banks are low on the west side of the lake but on the east side slope back irregularly to a height of 40 or 50 feet.

As shown on the map, the white space indicates the present water area. The black area outside shows the marsh and former lake area acquired by the company. The outside line of the black is said to

have followed the line of 10 foot marl. This is copied from the company's survey sheet and shows a water area in Little Turkey Lake of about 75 acres, and land area outside, of 125 acres, or a total of 200 acres. Big Turkey Lake has a water area of about 250 acres and an equal amount of marl land around, or a total of 500 acres, making 700 acres for the deposits around and beneath the two lakes. Big Turkey Lake is over a mile and a half long by one-eighth to three-eighths of a mile wide and is divided nearly in two near the north end.

MARL.—It is claimed that the marl runs from a thickness of 10 feet on the edge of the area shaded black, to a maximum depth of 45 feet. It was not learned how much of the area was under water shallow enough to allow the marl beneath to be worked. In October, 1900, the marl was being secured from the border of the marsh, just north of the cement factory. The pit as exposed, showed muck one foot, marl nine feet.

The *average* of six analyses of marl from Big Turkey Lake, as furnished by Prof. W. R. Oglesbey, the chief chemist of the Wabash Portland Cement Co., was as follows:

Carbonate of lime ($CaCo_3$)	91.14
Magnesium oxide (MgO)	1.31
Alumina (Al_2O_3) and Ferric oxide (Fe_2O_3)	.86
Silica (SiO_2)	.85

The clay used in the making of the cement is hauled from a point about two miles northwest of the factory. It comes from a bed of drift clay, a section of which is as follows:

1.	Sand	15 inches.
2.	Clay	6 feet.
3.	Clay mixed with pebbles	3+ feet.

The surface sand is stripped and the first six feet of clay is used, the remainder containing too many pebbles of lime and other minerals of drift origin to be available for cement making. The clay used is light brown, fine-grained and free from grit. It may be classed as exceedingly pure for a clay of glacial origin. An *average* of eight analyses of this clay kindly furnished by Prof. Oglesbey, was as follows:

Silica (SiO_2)	56.74
Alumina (Al_2O_3)	19.43
Ferric oxide (Fe_2O_3)	4.83
Lime (CaO)	7.27
Magnesia (MgO)	3.05
Loss on ignition	10.39
Total	101.71

LONG AND PRETTY LAKES.

Large Marl Deposit, Mostly Under Deep Water.

LONG LAKE.

Long Lake lies in a northwest and southeast direction in sections 22, 26 and 27 (36 north, 11 east), Milford Township. It is about one

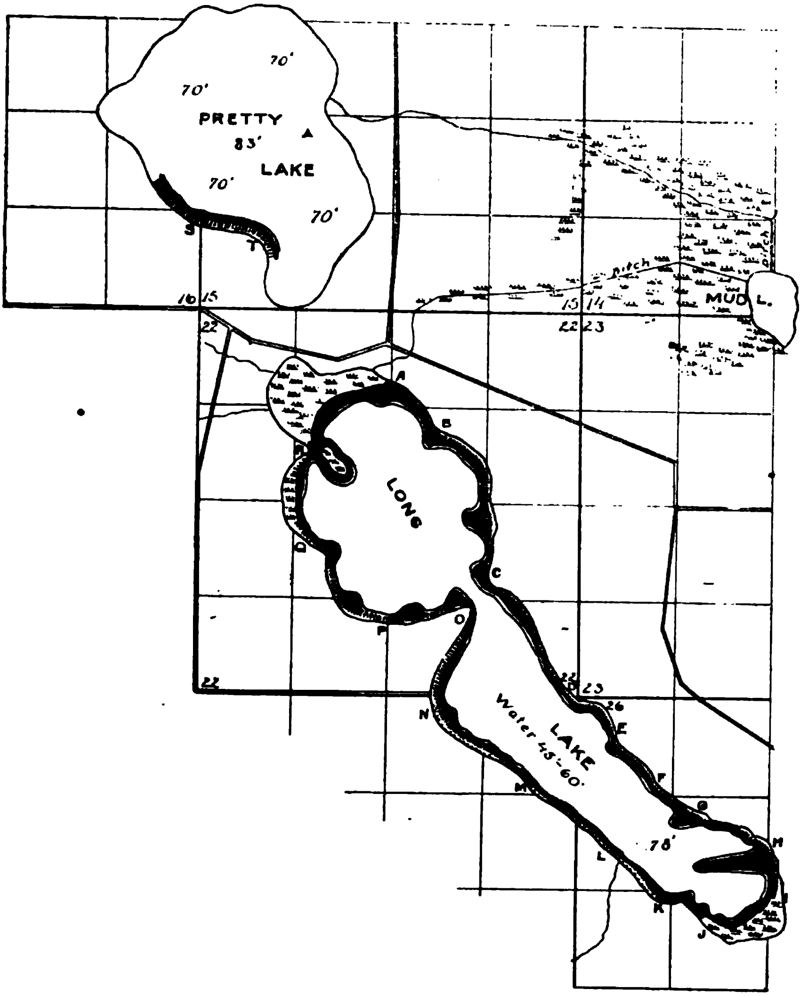


Fig. 18. Map of Pretty and Long Lakes, Lagrange County, Ind.

mile from the Chicago Division of the Wabash Railway. The lake is nearly two miles long by from one-quarter to one-half mile wide. A long point from the west side nearly divides it into two parts,

giving it a striking resemblance to Big Turkey Lake, Lagrange County. The head and foot of the lake have been somewhat reduced by the encroachment of the marsh.

In the southern part of the lake the belt of shallow water is usually narrow with one unusually long point near the south end. In the north part of the lake the shallow water will average somewhat wider, due to the existence of several points extending out into the lake. The deep water runs from 15 to 60 feet, the deepest being 78 feet near the southern end. The banks around the lake are unusually steep and high.

MARL.—Judging from stumps and logs in the water around the margins of the lake it would appear to have been raised a little. Partly as a result the bottom is hard close to shore and in water under two feet deep. Generally, where the water has reached a depth of three feet the marl is found to be over ten feet deep and at most points over 16 feet deep. From (A) to (D) none of the drillings in two feet or over of water reached the bottom of the marl at 16 feet. At (D) the marl is shallower, being only nine feet deep in four feet of water, and is overlain by sand. At (E) it is deep and at (F) begins to get shallow again, so that at (G) it is only one foot thick in two and one-half feet of water, with six inches of sand over and seven feet deep in four feet of water with three inches of sand over. The marl is deep on the long bar running out from (H) and around the south end of the lake nearly to (L). From (L) to (N) the marl is shallower, being absent in two and three feet of water and only five or six feet deep on the six-foot water-line. Though one drilling showed only six feet of marl under seven feet of water, most of the tests in water of that depth or more did not reach the bottom of the marl at 16 feet. Between (N) and (O) the marl in two feet or more of water is over 14 feet deep. From (O) to (Q) the marl runs eight or nine feet deep in two feet of water near shore, but in two or three feet of water, on the points shown, extended to below reach of drill. Around the marshy island at (R) the marl is deep but inclined to be mucky and with usually a little muck on top. There is little doubt but that marl averaging over 10 feet in thickness underlies almost the entire deep water area of the lake.

PRETTY LAKE.

A lack of boat prevented the complete testing of this lake. It lies in sections 15 and 16 (36 north, 11 east), just northwest of Long Lake, from which it is separated by an elevated ridge about one-third

of a mile in width. The lake is over three-quarters of a mile long by one-half a mile wide, with an area of more than 200 acres.

It is described as a very regular basin 83 feet deep in the center and shallowing gradually toward shore to 70 feet, then rising rapidly to the shallow water bench. The surrounding topography is much the same as that of Long Lake. Tests for marl were made by wading along the southwest shore. Thus at (T), in one foot of water 25 feet from shore, the marl is four feet deep and twice that depth in two feet of water at 40 feet from shore. In three feet of water at 60 feet from shore the marl is 11 feet deep and a little further out extends to below 16 feet. About the same results were obtained by tests at various other places along the south or southwest shore.

There is undoubtedly enough marl in the two lakes under consideration to justify the erection of a large cement factory, but until appliances are invented for securing the marl from beneath deep water it can not be utilized.

ADAMS AND EVE LAKES.

Large Marl Deposit, Mostly Under Deep Water.

ADAMS LAKE.

Adams Lake lies two miles northeast of Wolcottville, Lagrange County, in sections 23, 24, 25 and 26 (36 north, 10 east), Johnson Township. Its southern edge is a mile north of the Chicago Division of the Wabash Railway and its western edge a little over a mile east of the Grand Rapids & Indiana Railway.

The lake has a length of over one mile by a width of over a half-mile and an area of 320 acres. A long point, but slightly submerged, extends out from the northeast shore nearly cutting off the east end. This point had, when examined, only a few inches of water over it. The shore at most points runs out gently for 100 to 150 feet, to a depth of four to eight feet of water, then in a few feet descends rapidly to deep water. The deep water is said to run from 40 to 75 feet deep with 93 feet of water off from the long point mentioned. The shores of the lake are at most points elevated with a noticeably high hill at (G).

Marl.—A few inches of marl is often found close to shore, but usually it does not reach a thickness of three feet until 50 or 75 feet from shore, where the water is perhaps two feet deep. Where the water is three feet deep the marl is apt to run from five to ten feet deep. After reaching four feet of water the marl quickly

thickens to over 10 or 12 feet. The conditions around the lake are fairly uniform and as given above. The long point has no marl on its crest, which is composed of sand and gravel, often quite coarse. The marl appears to be of good quality.

EVE LAKE.

This lake lies in section 24, just northeast of Adams Lake. It has an area of about 25 acres and a reported depth of 65 feet. Sur-

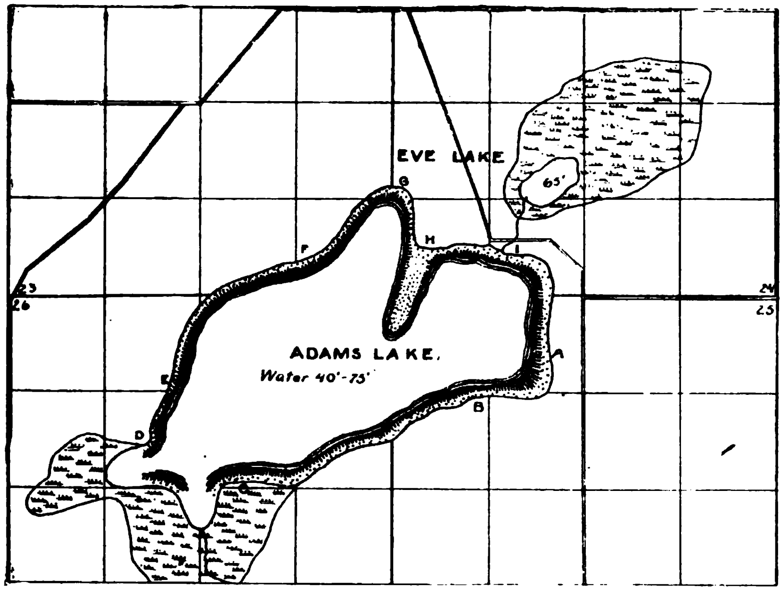


Fig. 19. Map of Adams and Eve Lakes, Lagrange County, Ind.

rounding the lake is about 50 acres of marsh showing much bare marl. This, it is claimed, has been tested all over with a 15-foot pole without finding bottom except at the edges.

There is very probably an acreage and thickness of marl, beneath and around these two lakes, sufficient to furnish a large factory with cement material. The larger deposit in Adams Lake is, for the most part, however, covered with deep water, and is, therefore, not at present available.

OLIVER AND OLIN LAKES.

Large Marl Deposit, Mostly Under Deep Water.

These lakes, which are contiguous, lie in sections 17, 18, 19 and 20 (36 north, 10 east), Johnson Township. They are about a mile and a fourth west of the Grand Rapids and Indiana Railway, and two and a half miles northwest of Wolcottville. Oliver Lake is over a mile long from east to west and nearly a mile wide from north to south, with an area of about 600 acres. Olin Lake is more irregular in shape, with a length of one-half mile and a width of a quarter of a mile, covering probably less than 100 acres.

Oliver Lake has a broad expanse of shallow water in the north-eastern part, but around the remainder of the lake the shallow water belt is comparatively narrow. There is a considerable shoal in

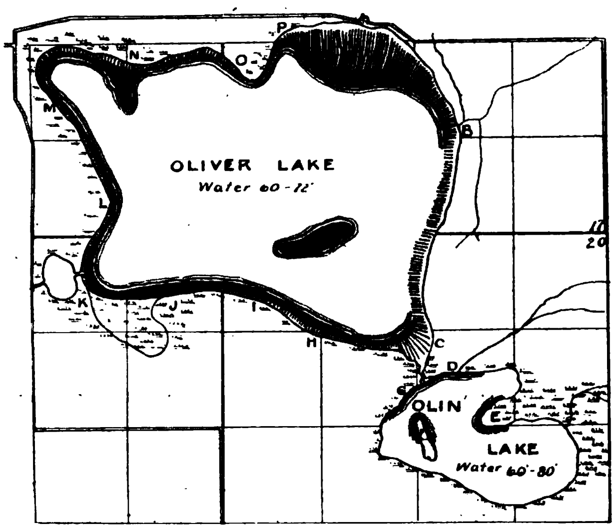


Fig. 20. Map of Oliver and Olin Lakes, Lagrange County, Ind.

the southeast part of the lake over which the water is from one to three feet deep. The deep water in the eastern half of the lake runs from 60 to 72 feet in depth.

The shallow water belt in Olin Lake is very narrow, being only a few yards in width at the most; when the bottom slopes down rapidly into deep water, which ranges up to 80 feet in depth.

Marl.—At (A) the shore is hard, but the marl sets in a short distance out, and though the water remains two feet deep for a long distance, the marl gradually increases from one foot to over 12 feet

and in three feet of water extends to below 16 feet. Along the east side of the lake the marl is shallower, running up to eight feet in two feet of water in one place, but generally only showing five or six feet of marl in four feet of water. In seven feet or over of water the marl is deep. It is also deep on the shoal, and along the south side of the lake the bottom of the marl was not reached even in one and two feet of water. Along the western and northwestern side of the lake the conditions are practically the same. Though the shallow water belt is narrow the marl, even in two feet of water, reached to below the pole. All of the tests in Olin Lake found marl to below 16 feet.

The deposit of marl in the two lakes is sufficient to supply a large factory for many years, but the greater part of it is not at present available, on account of the depth of the overlying water.

NAUVOO LAKE.

Not a Workable Deposit.

This lake lies beside the Chicago Division of the Wabash Railway, about two miles east of Wolcottville. The tests for marl were limited to a line of drillings along the channel from the lake to the ice-house beside the railway. These were made about 100 yards apart, starting near the railway and extending to the lake. All of these showed muck varying in thickness from two to 16 feet, with the underlying marl from one foot to 14 feet in depth. The amount of muck was deemed too great to allow the working of the deposit.

WITMER, LONG, THIRD, DALLAS AND ATWOOD LAKES.

Large Marl Deposit, Mostly Under Deep Water.

As these lakes, except Atwood, are all openly connected, they will be treated as containing a single deposit. They lie west of Wolcottville, Lagrange County, in sections 29, 30, 31, 32 and 33 (36 north, 10 east), Johnson Township, and section 25 (36 north, 9 east), Clear Spring Township. Atwood and Witmer lakes are each but little over one-quarter of a mile from the Chicago Division of the Wabash Railway and Witmer Lake about a mile from the Grand Rapids & Indiana Railway.

Witmer Lake is an irregular oblong, a mile long by a quarter to a third of a mile wide. Long Lake is more like a wide, deep channel than a lake. It is a mile long by an eighth of a mile or less wide. Third Lake is an irregular body of water, a half mile wide from east

to west and a little over that from north to south. The northern part narrows down to channel-like proportions, with Pickerel Bay projecting to the east. Dallas Lake has a length of about a mile

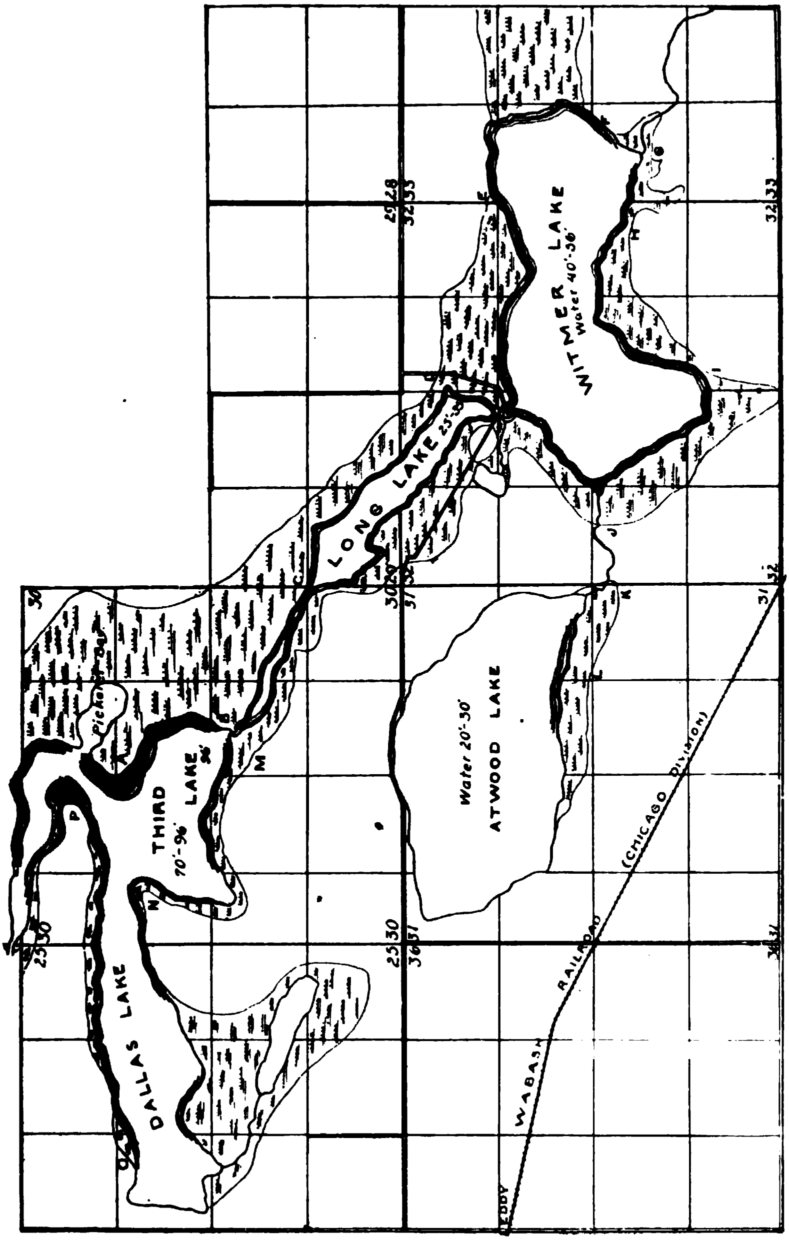


Fig. 21. Map of Atwood, Dallas, Third, Long and Witmer Lakes, Lagrange County, Ind.

and a width of a quarter of a mile or less. Atwood Lake is more regularly oval than the others with a length of over three quarters of a mile and width of nearly half a mile.

Though the hills surrounding these lakes are of only moderate height and usually separated from the lakes by a varying width of marsh, the lakes themselves have a good depth and, in the case of Third Lake, a surprising depth. Except a strip along the east side of Third Lake, the belt of shallow water around all of the lakes is very narrow, usually not more than a few yards or at most a few rods wide.

Witmer Lake has a depth of from 40 to 56 feet; Long Lake a depth of 25 to 35 feet. Third Lake showed a depth of 75 feet or more all over the deep water area with a maximum of 96 feet within 20 rods of the inlet. Atwood Lake is shallow, running from 20 to 30 feet. Around these lakes, somewhat as suggested on the accompanying map, is an extensive marsh area. Back of that the hills slope upward to moderate elevations. This chain of lakes forms the source of the northernmost branch of the Elkhart River, the upper course of which is characterized by passage through very extensive marshes, and lakes of considerable depth in the midst of them.

Marl.—With the exception of a small area of sandy bottom around the inlet of Witmer Lake, the shores of these lakes show marl at every point and except at a point near (E) on Witmer Lake and one on the north side of Long Lake, the marl extended to below reach of drill at every point tested. At the two points mentioned bottom was found at 15 feet. From the depth of the marl at the edge of the water it would appear evident that in many places it runs back under the marsh. Tests at one or two points showed that back from the water the marl quickly gets thinner while the overlying muck as rapidly thickens. The largest local deposit of marl was found on the east side of Third Lake at (A). At this point is a large area of shallow water, beneath which the marl is very light in color and comes within a few inches of the surface. In the sunlight this glitters with the white lustre of burnished silver, due to the milky color imparted to the water by the underlying marl. There is little doubt but that a large portion of the marsh east and south of Pickerel Bay is underlain with a thick deposit of marl, but the conditions were such that a detailed examination could not be made. Atwood Lake was only examined along part of the south side. The marsh here is, for the most part, a quaking meadow with a good depth of rather mucky marl below.

Judging from the thickness of the exposed or shallow water marl, around these lakes, the greater portion of their deep water area is underlain with a deposit of good depth. That at present available is mostly in Third Lake. On account of the excellent railway facilities and the quality of the marl, which appears of the best, the deposit will doubtless be developed as soon as appliances for utilizing the deep water marl can be used.

NOBLE COUNTY.

REFERENCES —

1859.—Richard Owen, Geol. Reconn. of Ind., p. 207.

1873.—G. M. Levette, Fifth Ann. Rep. Geol. Surv. of Ind., p. 447.

1875.—*Id.*, Seventh Ann. Rep. Geol. Surv. of Ind., pp. 487, 492.

1893.—Dr. C. R. Dryer, Seventeenth Ann. Rep. Ind. Dept. Geol. and Nat. Res., p. 17.

1899.—Frank Leverett, Water Supply and Irrigation Papers, U. S. Geol. Surv., No. 21, p. 31.

Noble County is in the second tier of counties south of Michigan and in the second tier east of Ohio. It is bounded on the north by Lagrange, on the east by Dekalb, on the south by Allen and Whitley, and on the west by Elkhart and Kosciusko counties. The county contains 417 square miles and lies between 868 and 1,018 feet above sea level, the lowest point being the Elkhart River on the western line of the county and the highest the summit in Wayne Township, three miles east of Kendallville. The following is the elevation in feet, above tide, of the more important railway stations in the county: Albion, 919; Avilla, 976; Avilla Summit (B. & O.), 1,007; Brimfield, 944; Cromwell, 930; Kendallville, 974; La Otto, 881; Ligonier, 885; Rome City, 933; Swan, 885; Wawaka, 895.

The county is well supplied with transportation facilities, being crossed by three railways and touched by two more. The Grand Rapids & Indiana passes north and south through the eastern part; the Baltimore & Ohio, east and west through the center, and the Lake Shore & Michigan Southern, east and west through the northern tier of townships. The Eel River Division of the Wabash crosses the extreme southeastern corner, and the Chicago Division of the same system touches the northern border for about three miles in Orange Township.

The surface of the entire county is thickly covered with drift, the known thickness of which ranges between 169 and 485 feet. The greater part of this drift covering belongs to the interlobate

moraines of the Erie and Saginaw lobes. The Salamonie or Third Erie moraine crosses the southeastern corner of the county forming the surface of Swan and a small portion of that of Greene and Allen Townships. The Mississinewa or Fourth Erie moraine covers the townships of Greene, Jefferson, Allen, Orange and Wayne. The western part of the county is covered with the Saginaw Drift. On account of the intermingling or merging of debris from so many different glacial invasions, the surface of the county is extremely diversified. High rounded domes, hills and ridges alternate with deep valleys and level plains in rapid succession. Many of the depressions form water-tight basins, occupied by lakes either present or extinct. The latter far outnumber the former, the combined area of the marshes, which occupy the sites of former lakes being estimated at 15 per cent. of the total area of the county. Many of these marshes still retain a small pool of open water at the center, the last vestige of a once noble expanse of water, whose area has become gradually lessened by the encroachment of aquatic vegetation and by the dredged ditches of mankind.

The number of lakes still existing in the county probably exceeds 100, but the great majority of them might be termed "ponds," as they are less than 40 acres in extent. Nineteen, which contained an area of 150 or more acres each, were visited during our investigation of the marl deposits. A number of these were adjacent, the marl, if present, being termed as one deposit, even though beneath or surrounding two or three lakes. But four deposits were found in the county which were deemed workable under the present conditions of securing marl. Three others had a bed of sufficient area and thickness, but mostly beneath deep water. At the remainder the marl was not found in sufficient quantity to be available for the manufacture of cement.

TAMARACK LAKE.

Large Deposit, Mostly Under Deep Water.

This lake lies in section 6 (35 north, 11 east) and section 1 (35 north, 10 east), in Wayne and Orange Townships. It was formerly nearly a mile and three-quarters long with a long arm extending out from the northeastern side. By the removal of a dam and the ditching of the outlet it has been to a large degree lowered and reduced to a crescent-shaped body of water three-quarters of a mile long by less than a quarter of a mile wide. On account of this lower-

ing, the water area is surrounded on all sides by marsh-land, the widest extent of which is on the south and east sides. The lake contains but little vegetation except at the margins, where *Chara*, rushes and spatterdock are, in places, abundant. The maximum depth of water found was 40 feet. Along the west and south sides it was almost, everywhere, 15 feet deep at a distance of 20 feet from shore.

MARL.—The present water area is probably wholly underlain with a thick deposit of marl as, except where the township line meets the south shore, the marl extends to below 16 feet at every point along the narrow, shallow water area. Only the marsh-land south and southeast of the lake between (A) and (B) was tested. Begin-

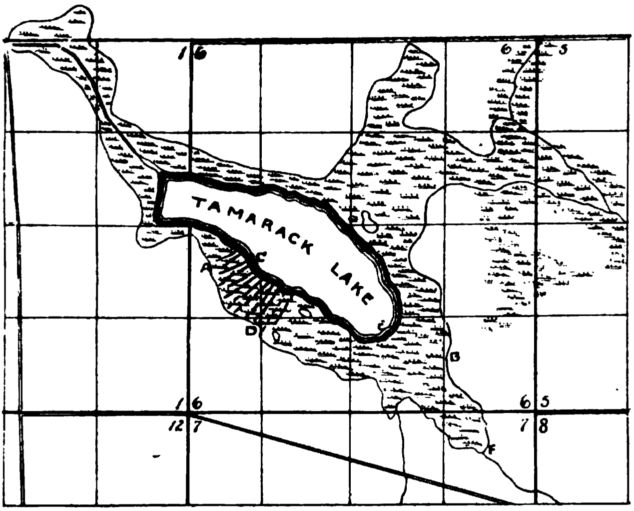


Fig. 22. Map of Tamarack Lake, Noble County, Ind.

ning at the water's edge opposite (C), four bores were put down, 10 rods apart, on a line to (D). These resulted as follows: (1) muck three feet, marl nine feet; (2) muck two feet, marl 11 feet; (3) muck six inches, marl 15 feet; (4) muck one foot, marl 12 feet. At the margin of the former water area, five rods south of number (4), the marl had wholly disappeared. Two bores, numbers (5) and (6), 10 rods apart, west of number (4), gave respectively nine and 10 feet of marl beneath one foot of muck. Twenty rods west of number (6), near (A), the muck had increased to four feet and the marl diminished to six feet in thickness. Twenty rods north 18 feet of muck only was found, and west of this to the township line no marl was found beneath 18 feet and more of muck. East of the quarter section line (C and D) the marl occurs 10 to 12 feet in depth for

about 10 rods and is then gradually replaced by muck, so that not over 12 to 15 acres of this portion of the marsh are underlain with marl. A number of tests in the marsh, in a southeasterly direction to the end of the lake, found only small isolated patches of marl, the muck everywhere predominating. The same thing holds good of the 60 acres or more of marsh southeast of the lake (E to F), where but one or two of many bores, with 18-foot auger, showed marl.

While the deposit beneath the present water area, combined with that in the marsh, is doubtless large enough for cement making, the amount under *shallow* water and in the marsh is not sufficient to justify the erection of a factory at the present time.

SYLVAN LAKE.

Not a Workable Deposit.

This lake, more commonly known as "Rome City Reservoir," is wholly artificial, being formed in 1837 by a dam thrown across a small tributary of the Elkhart River, to create a feeder for the proposed Michigan and Erie Canal. It adjoins Rome City on the east and the G. R. & I. Railway runs along its western border. The lake is nearly three miles long by one-half a mile wide, with an area of 1,200 or more acres. Its depth runs from 17 to 30 feet and its outline is very irregular, with numerous points, bays and narrow channels. Several islands, prettily wooded with oak and other timber, dot its surface and furnish delightfully cool and shady retreats for picnic and boating parties. The "Island Park Assembly," an institution under the management of the Methodist Episcopal Church, holds here its regular summer sessions. The lake has several times been well stocked with fishes by the U. S. Fish Commission, and furnishes excellent sport for all interested in the pursuit of the finny tribe.

Marl.—Being artificial, no marl occurs beneath its waters. In many of the bays and inlets a deposit of muck is slowly accumulating by the decay of water-lilies, rushes and other aquatic vegetation.

In the report of this Department for 1875, Dr. Levette states that "In a bluff that formed the border of a lake now filled up by vegetation, about one mile north of Rome City, a ditch has exposed a deposit of marl or fresh water chalk several feet in thickness. Other heavy deposits were reported in the same neighborhood. In the absence of a better article, this might be burned and used for

making mortar, but its chief value lies in its fertilizing properties when spread over the clay lands of the vicinity, after having been burned and slaked."

"An analysis of this marl showed the following composition in 100 parts:

Water at 212 degrees F	3.00
Carbonic acid and combined water	41.00
Insoluble silicates	.70
Oxide of iron	a trace.
Alumina	1.00
Lime	49.84
Magnesia	4.10
Sulphuric acid	.03
Phosphoric acid	.52
Total	100.19

"This chalk shows a remarkable degree of purity, the insoluble matter being less than one per cent., and it contains only a trace of iron. The discoloration is removed by ignition; it is pulverulent when dry and soft like mortar when first taken from the bank, and may be pressed into pencils and will mark like the common English chalk."*

LONG AND ROUND LAKES.

Large Deposit, Mostly Under Deep Water.

These lakes lie just north and northeast of Kendallville in sections 27 and 28 (35 north, 11 east), Wayne Township.

Long Lake is a mile long and has a width varying from a few rods toward the eastern end to one-quarter of a mile near the western end. Round Lake has been lowered several feet, thus materially reducing its water area. It is at present nearly three-quarters of a mile long by three-eighths of a mile wide and is almost divided in two by a point which projects out from its northwestern shore, and by a long island near its center.

The area around the basins of these lakes is high and rolling except for a marsh at the head of Round Lake and another at the foot of Long Lake. Around most of Long Lake and on the eastern side of Round Lake the banks rise abruptly from the water. The western side of the latter lake is at present occupied by an extensive marsh which covers at least one-third of the old lake area. Around both lakes the belt of shallow water is very narrow.

* Levette, loc. cit., pp. 493, 41.

MARL.—Long Lake showed marl to below 16-foot drill on the north side and at the west end, even where the water was only six inches or one foot deep. Along the south side of the lake the conditions vary greatly. At (M) the marl is over 15 feet deep close to shore in one foot of water. Going toward (L) it thins until it is only six feet thick in six feet of water; then deepens until it is 12 feet deep in one foot of water. Toward (K) the marl nearly runs out, and while here and there is a foot or two thick, in the main only sand and gravel is found out to 16 feet of water. The marl is deep but mucky in the bend at (J). Along the south side of the narrow neck of the lake no marl was found, but farther east at (H) it deepens rapidly so that as much as 12 feet of marl was found at the water's edge. Marl probably extends from one lake to the other.

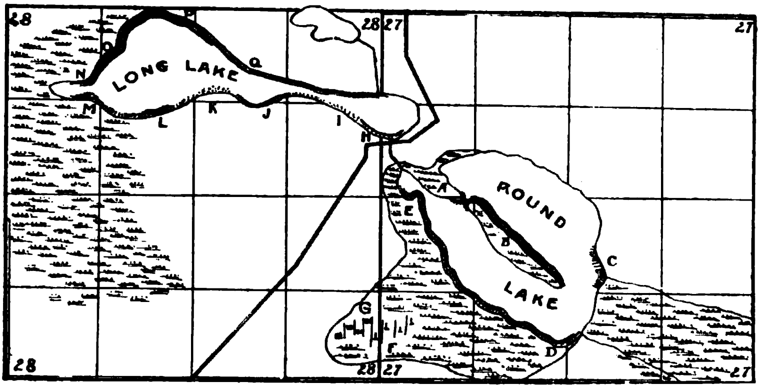


Fig. 23. Map of Long and Round Lakes, Noble County, Ind.

Tests on Round Lake along the south shore showed either 12 or 13 feet of marl at the water's edge with remarkable regularity. The same depth was found between the point and island. Along the north side of the island the marl is deeper, in most cases being over 16 feet thick and suggesting that the island is largely composed of marl. Tests made in the marsh at (F-G) showed from three feet to 12 feet of muck, underlain by from one to five feet of marl, the thickest marl coming under the thinnest muck. Doubtless still thicker marl underlies parts of this old lake bed, but circumstances prevented us from making a detailed test of its area.

From the results of tests made we feel safe in believing that the entire deep water area of the two lakes overlies a thick deposit of marl. The amount at present available is not, however, sufficient to term it a workable deposit.

WALDRON, JONES AND STEINBARGER LAKES.

Workable Deposit, Partly Under Deep Water.

This group of lakes lies about two miles west of Rome City in sections 7 and 18 (35 north, 10 east), and sections 12 and 13 (35 north, 9 east), Orange and Elkhart townships, and are tributary to the North Fork of the Elkhart River.

Jones Lake is nearly rectangular; is half a mile long by a quarter of a mile wide, with an area of about 100 acres. Waldron Lake is an irregular shaped body of water, more like an enlargement of the Elkhart River than a lake. Following its windings it has a length of

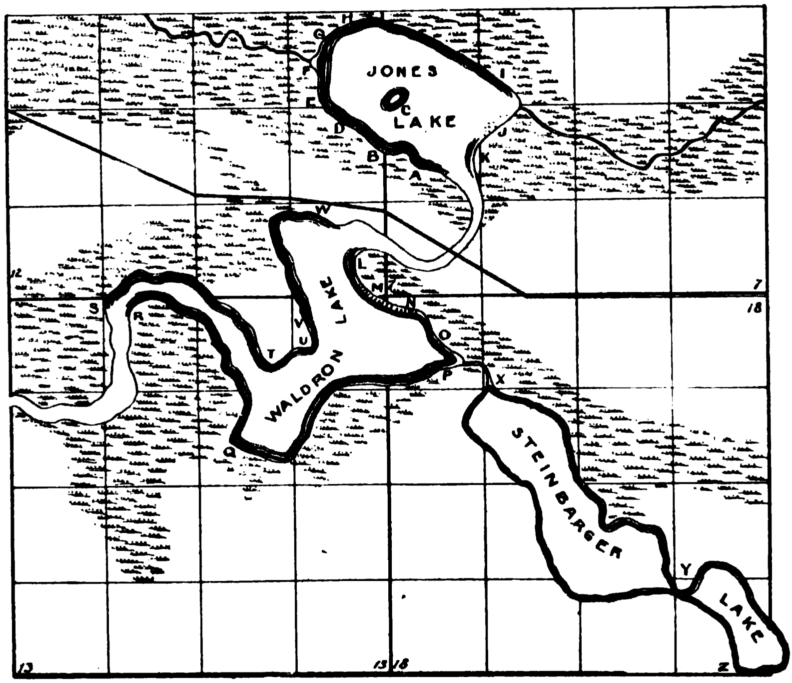


Fig. 24. Map of Waldron, Jones and Steinbarger Lakes, Noble County, Ind.

a mile or more with a width ranging from a few rods to a quarter of a mile. Toward the west it gradually narrows down to the proportions of a river. An open channel connects this lake with Jones Lake. Steinbarger Lake has a length of one mile and an average width of less than a quarter of a mile. A point from the north side near the southeast end nearly divides the lake into two unequal parts.

Except along the south side of Steinbarger, the immediate shores of these lakes are nearly everywhere flat and marshy. Back of these extensive marshes the land rises into rolling upland. As a rule the belt of shallow water is narrow, being especially so in Steinbarger Lake. Jones Lake has a maximum depth of 30 feet, and a small island rises a little west of the center. Waldron Lake averages 30 feet in depth with a maximum near the south end of 47 feet. Steinbarger Lake has about the same depth with a maximum, near the head, of 39 feet.

MARL.—In Jones Lake the marl ran to below 16 feet at nearly every point tested in water from one to 12 feet in depth. In places the marl gets shallow toward shore but generally it extends to below 16 feet in one foot or less of water, indicating that it tends to run back under the marsh. The island appeared to be all marl. In quality, the marl of this lake was usually dark and mucky, especially toward the northwestern corner, where it appeared to be more muck than marl.

In Waldron Lake the marl gets shallow toward shore at the east side at (M), in two feet of water running from four to seven feet in thickness. It is nine feet thick in three feet of water and then increases rapidly. At (U) on the north side the marl was only 10 feet thick, but at every other point tested it ran to over 16 feet. Time did not permit the testing of the extensive flats around the lake, but their appearance seemed to favor the idea that some marl would be found beneath them. The marl here appeared much whiter and more solid than in Jones Lake.

In Steinbarger Lake none of the tests found the bottom of the marl at 16 feet. The marl here was not as clean as in Waldron, and much softer, especially in the southeastern end.

The above three lakes are so closely connected as to form practically one deposit. A switch three miles in length would reach Waldron Lake, from either the L. S. & M. S or the G. R. & I railways, thus giving excellent transportation facilities, and there is no doubt but that the acreage and thickness of shallow-water marl now available in and around the lakes is large enough to warrant the investment of capital in its development for cement making.

SKINNER LAKE.

NOT A WORKABLE DEPOSIT.

Skinner Lake lies about two miles east of Albion in sections 15 and 16 (34 north, 10 east), Jefferson Township.

The lake occupies a shallow basin 25 to 30 feet deep surrounded by low rolling land. It has an extreme length of nearly a mile and extreme width of half a mile, with an area of about 150 acres. The shores are low and devoid of points of interest.

MARL.—The distribution of marl on this lake is extremely irregular. At (A) is no marl, but muck to below 16 feet. Toward (B) marl sets in, being four feet deep in one foot of water but in deeper water is replaced with muck. Thus in four feet of water the muck is seven feet deep and a little further out is more than 16 feet in depth. The muck continues to 16 feet of water and beyond. At (C) the marl is six feet deep in one foot of water, four feet deep in four feet of water and has thinned out before eight feet of water is reached, where the bottom is hard. From (D) to (E) no marl was found. At (F) the marl is thick, the bottom not being reached in water eight feet or over deep. Going on to (G) it disappears and is replaced by muck which is over 14 feet deep in two feet of water, and bottom not reached farther out. At (H) a little marl appears below the muck. From (H) to (J) no marl was found, the muck being everywhere to below 16 feet. At (K) six feet and more of greenish marl was found under five feet of muck in five feet of water. Then for a distance the bottom is all sand at all depths within reach. At (M) in shallow water, marl appears below a considerable thickness of muck, but drillings in 10 feet or over of water showed only muck. At (N) the bottom is hard. From (O) to (P) the muck is deep. At (Q) the marl runs to below 16 feet at all depths of water but is mucky. At (R) there is a foot or two of mud and marl in water from one to five feet deep, but in deeper water the bottom is hard. From (S) to (T) the muck is thick.

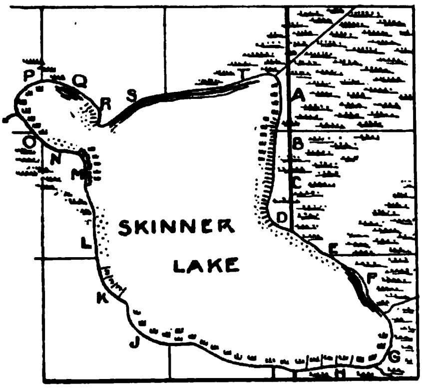


Fig. 25. Map of Skinner Lake, Noble County, Ind.

The tests showed that the marl is not sufficient in quantity or suitable in quality for cement making.

DIAMOND LAKE.

Large Deposit, Mostly Under Deep Water.

Diamond Lake lies in sections 31 and 32 (35 north, 9 east) and sections 5 and 6 (34 north, 9 east). It is two miles south of the L. S. & M. S. Railway and three miles north of the B. & O. Railway. The lake is five-eighths of a mile long by three-eighths of a mile wide and of a regular oval shape. On the south the country is rolling or flat but on the north rises one of the most abrupt ranges of hills occurring in the drift region of the State. In the words of Dr. Dryer:* "They are as rough and irregular a pile of gravel knobs as can be found in Indiana, rising 150 to 200 feet above the lake, with a southern descent almost too steep for a horse and wagon. The range is two and a half miles long east and west, and from one-half to three-fourths of a mile wide. It is completely isolated by the valley of the Elkhart on the east and north, and the valley of the lakes and their outlet on the south and west, and forms one of the most remarkable as well as conspicuous features of the region. The Diamond Lake hills stand like an Egyptian pyramid amid the ruins of an ancient city, a monument to show us what the Saginaw Glacier could do upon occasion."

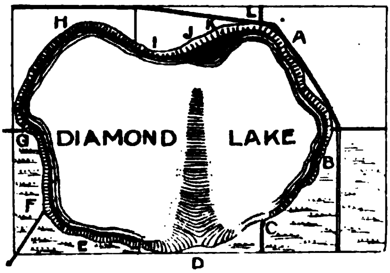


Fig. 26. Map of Diamond Lake, Noble County, Ind.

The depth of Diamond Lake is unusual for a lake of its size, averaging 50 feet, with a maximum of 82 feet. A long bar extends out from the south shore nearly across the lake. When visited in October, 1899, this had only a few inches of water over it. The shore at most points runs out gently for a way then descends rapidly to deep water. Although the Elkhart River is but one-half mile to the eastward with no elevation between, yet the outlet of Diamond Lake flows southwesterly into Eagle Lake and thence, by a small stream, cutting the highland, northward into the Elkhart near the town of Rochester.

Marl.—Around most of the lake the marl is deep, sometimes shallowing rapidly at the shore and sometimes running out beneath

* Loc. cit., p. 24.

the marsh bordering the shore, the latter condition being due to a recent lowering of the lake by ditching. Along the east side the shore is sandy, but in the water the marl quickly reaches a depth of 16 feet or over. At (A) the sand has washed down over the marl, making it appear as though absent. Thus in two feet of water is found six inches of sand, then 10 feet of marl. Toward (C) the marl gets more shallow again. On top of the long bar it runs from one foot to four feet in thickness, increasing to seven feet on the flanks where the water is five feet deep, then thinning down until it runs out in 12 feet of water and only hard bottom is found beyond. Toward (E) the marl gets thicker, being nine feet thick in six inches of water, 13 feet thick in two feet of water and below reach of drill in deeper water. Along the west end of the lake none of the tests in the water reached the bottom of the marl which here runs back from the water's edge. From (I) to (L) the marl is somewhat variable at similar depths, about half of the drillings failing to reach the bottom, while others found 12 feet or more.

On the whole the tests showed the presence of a large deposit of good marl, but as most of it is beneath 10 feet or more of water it is not, at present, available.

EAGLE LAKE.

WORKABLE DEPOSIT.

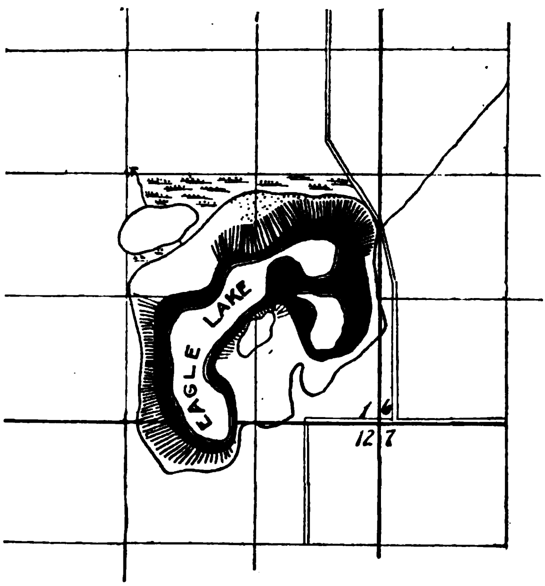


Fig. 27. Map of Eagle Lake, Noble County, Ind.

Eagle Lake lies a little southwest of Diamond Lake in section 6 (34 north, 9 east) and sections 1 and 12 (34 north, 8 east). It is two miles north of the B. & O. Railway and three miles south of the L. S. & M. S. Railway. The size of the lake has recently been much reduced by draining, so that the present water surface is comparatively small. It has a length of half a mile or more and a width of a few rods to one-eighth of a mile. The shores of the old lake basin on the north and west are low, while those on the south and east are abrupt. As already noted, the outlet flows northward into the Elkhart River.

MARL.—Though small, this lake is rich in marl. Except along the southwest shore none of the drillings in the water reached the bottom of the marl. Tests out on the shore indicated that while at places the marl extended back with gradually lessening depth to the old shore line, at other places it did not extend back more than half way. The marl appeared of good quality.

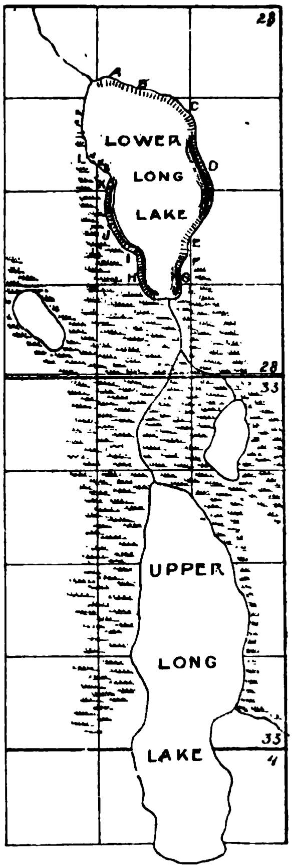


Fig. 28. Map of Upper and Lower Long Lakes, Noble County, Ind.

The total area underlain with marl in and around Eagle Lake is, at a low estimate, 200 acres, and its average depth is probably in excess of 20 feet. On account of its proximity to two important railways the deposit is an important one and in every way worthy of development for cement making purposes.

LONG LAKES.

NOT A WORKABLE DEPOSIT.

Long Lakes lie in sections 28 and 33 (34 north, 9 east) and section 4 (33 north, 9 east), York and Noble townships. Only the Lower Lake was examined.

This lake is less than three-quarters of a mile long by a little over a quarter of a mile wide. Upper Long Lake is one mile long by a quarter of a mile wide. The lakes lie in a narrow valley with high hills on either side, those east of the lake being especially rugged. As a rule the band of shallow water is narrow, in places the six-foot water line being within 10 or 15 feet

from the shore. The outlet of the lakes is to the northward into Elkhart River.

Marl.—Marl was found at nearly every point around the shore, but at most points was comparatively shallow. Thus at (A) in one foot of water five feet from the shore the marl is six feet deep. At 10 feet from shore in four feet of water it is 11 feet deep, while at 15 feet from shore in six and a half feet of water it is only nine feet deep. Toward (B) the marl reaches a thickness of 11 feet in two feet of water, no marl showing in one foot of water as before. At (C) one foot of marl is found in one foot of water and five feet of marl in two feet of water, with the marl increasing in depth toward (D) where, in two feet of water it is over 14 feet thick but mucky. At (E) and (F) the marl is about three feet deep in one foot of water, five to five and a half feet in two feet of water, and eight feet deep in four feet of water. At (G) there is more muck than marl. At (H) and (I) the marl has a depth of nine feet in one foot of water and 13 feet in two feet of water, marl at bottom but muck on top. At (J) 10 feet of marl occurs in four feet of water, good at the bottom only. At (K) the marl is eight feet deep in six feet of water, while at (L) only muck is found. On the whole the quality of the marl does not appear to be very good and the quantity beneath shallow water is not sufficient for the purpose of cement making.

DEER LAKE.

Workable Deposit.

This is a small lake which occupies part of section 25 (34 north, 8 east), Sparta Township. It is distant one and one-half miles south of the B. & O. Railway. The lake is only a little over a quarter of a mile long and about the same in width, with low marshy ground in nearly every direction around its borders. It has been lowered materially in recent years, thus decreasing its water area.

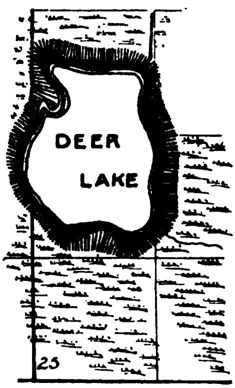


Fig. 29. Map of Deer Lake, Noble County, Ind.

Marl.—Though this lake is small the marl in its basin is above the average in thickness. Except in the northwest corner, all of the tests found marl to below 16 feet. Outside of the lake the marl extends back 75 or 100 feet. Thus at one point 50 feet back from the margin of the water the bare marl was 13 feet deep; 25 feet farther back

it was only 3 feet deep, and ran wholly out within 100 feet from shore.

The marl appeared to be of good quality, and there is deemed to be a sufficient quantity for cement making, as the area of the bed is probably 130 acres and its average thickness 15 or more feet.

LONG AND SAND LAKES.

Not a Workable Deposit.

These are two out of eleven lakes which lie in a chain across northern Greene Township in sections 3, 4, 8, 9 and 10 (33 north, 10 east). These lakes are all small and occupy a narrow valley flanked with high hills on the north and south. Their outlet is to the southward into Blue River, a tributary of Eel River.

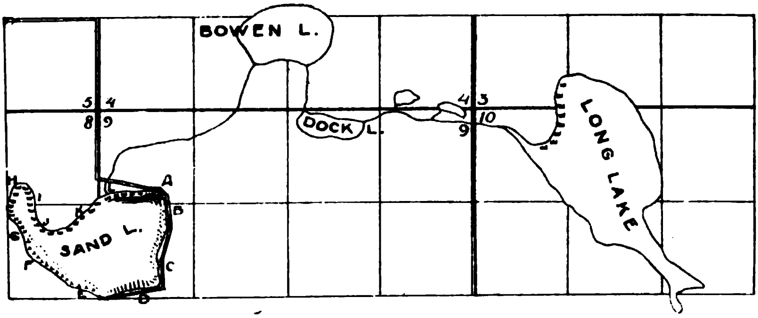


Fig. 30. Map of Sand and Long Lakes, Noble County, Ind.

Marl.—Long Lake, for lack of a boat, was only tested on the western side, where it revealed no marl at all. Sand Lake shows 10 feet of mucky marl in one foot of water at (A); but at (B) the marl has run out and there is only sandy bottom from (B) to (C). At (D) the marl is mucky and two feet deep in two feet of water; four feet deep in four feet of water, and at greater depths up to 16 feet, runs from three feet to zero in thickness. From (E) to (G) there is from one to three feet of muck in shallow water, or even out to 12 feet of water, but in 16 feet of water at every point the bottom is sandy. From (G) to (L) no marl is found, but everywhere the muck is deep, extending below drill in all tests. The amount of marl present is, therefore, too insignificant for further consideration.

MARL LAKE.

Thick Deposit of Doubtful Workable Size.

This is a small lake, east of Wolf Lake postoffice, in sections 10 and 11 (33 north, 9 east), Noble Township. It is about three-eighths by one-eighth mile in size and has an area of about 40 acres. It is largely surrounded by marsh land, beyond which the ground rises in rugged ridges.

Fig 31. Map of Marl Lake, Noble County, Ind.

Marl.—This lake seems to lack but little of being a solid marl bed. None of the tests in the lake with 16-foot drill reached the bottom of the marl, and around much of the shore the bare marl is exposed for 20 or 30 feet back, and extends still farther back, but with an ever increasing depth of muck over it. Up the ditch, at the west end of the lake, the marl is over 16 feet deep for a quarter of a mile, with from one to two feet of muck over it. Beyond that the marl is replaced with muck. At either side of the ditch the muck increases in thickness at the expense of the marl. There are several acres of marl additional in Little Marl Lake, just east of the other, and marl is reported as occurring extensively in the marshes in this neighborhood. While the acreage of marl in the lake and surrounding marshes is not large, its great depth renders it worthy of more detailed investigation than we could give it with the auger at our command.

Deep Lake, to the southwest of Marl Lake, has much aquatic vegetation around its margins. No boat was available for its exploration and the tests put down where it was possible to wade showed only muck.

BEAR AND HIGH LAKES.

NOT A WORKABLE DEPOSIT.

These lakes are distant from one another about one-half a mile, and lie southwest of Wolf Lake postoffice, in sections 7, 8, 17 and 18 (33 north, 9 east) and section 13 (33 north, 8 east), Noble and Washington Townships.

BEAR LAKE.

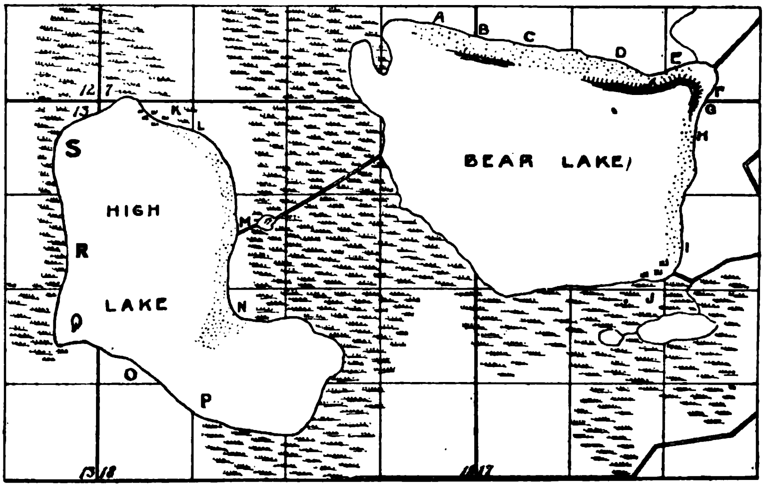


Fig. 32. Map of Bear and High Lakes, Noble County, Ind.

At the time of our visit in October, 1899, Bear Lake had a length of nearly a mile and a width of nearly three-quarters of a mile, with a water area of 320 acres. It was then a clean, compact body of water, with the banks of its north and east shores rising rather abruptly for 20 or more feet and then running back into a level or slightly rolling surface; while the south and west shores were bordered with extensive marshes, the area on the west between the two lakes being entirely a low marsh filled with dense aquatic vegetation. The water had a maximum depth of 50 and an average depth of perhaps 18 feet, the shallow water on all sides extending out well into the lake. In November, 1899, the lake was lowered six feet, thus destroying its natural beauty, by enlarging greatly the area of shallow water and causing great mud flats around its entire margin.

MARL.—Before the recent draining, Bear Lake had, for the most part, sandy and gravelly bottom in three feet or less of water. At (A) and (C) the bottom is clay instead of sand. In deeper water

some marl was found. Thus at (B), in 10 feet of water, the marl is six feet deep. At (D) in five feet of water, there is sand six inches, over marl 10+ feet in thickness. Going toward (E) the marl was 11+ feet and overlain by one foot of sand in four feet of water. At (F) and (G) the marl extends to below 16 feet in water four to nine feet deep, but is mucky and poor. From (H) to (I) no marl was found. At (J) the bottom is muck to below 16 feet, and the same conditions prevailed along the south and west shores.

HIGH LAKE.

Before the recent dredging this was one of the prettiest lakes in Indiana. Along its eastern border was a natural ridge of sand and gravel, 30 to 50 feet wide, 15 to 20 high, and sparsely covered with fine oak and other trees, thus forming a beautiful site for camping parties and summer cottages. The waters of the lake were then clear and sparkling, well stocked with fish and mussels—a delightful resort for anglers and boating parties. Now all is changed. To gratify the caprice of a few men, who wished to enhance their acreage of land, a ditch was dredged through the gravel ridge and the marsh beyond, and "High Lake" was converted into a low mud-hole. The fish and bivalve shells are dead or dying. Rank weeds and aquatic rushes and cat-tails are rising over the marsh and sand bars which were formerly covered with clear, pure water. Mud and ooze, black, slimy, disgusting to the sense of sight and smell, is everywhere about the margins. Like hundreds of others of the fairer bodies of Indiana's inland waters, it has yielded forever its natural beauty to the devastating hand of man.

In 1893, Dr. Dryer wrote of High Lake as follows: "It is interesting from the fact that its basin seems to belong to a type hitherto undescribed in Indiana. The western half of section 7, Noble Township, is occupied by a series of sand ridges, perhaps 20 feet high, extending north and south. At the north end of High Lake they divide into two branches which follow the east and west shores respectively. Thus the lake basin lies between the arms of the Y in a space which is nearly closed up by a cross ridge along the south shore. These ridges are generally of moderate slope and from 20 to 40 feet above the lake, composed chiefly of sand; but at the point on the east side, where the outlet leaves the lake, the ridge is not more than three feet high and composed almost entirely of small, angular boulders. At this point it was first observed and was mistaken for a beach ridge. A few excavations in the higher part of the ridge

show yellow sand intermingled with angular stones from the size of a man's fist to the size of his head. We evidently have here a specimen of the kames or eskers which are so numerous in other portions of the great morainic belt of North America."*

In its original condition the water area of High Lake was about one mile long by one-quarter to one-half a mile wide and with an area of 250 or more acres. The maximum depth of water was 30 feet. The bench of shallow water along the east side of the lake was very broad and near the bend in the lake extended out so that it was possible to wade fully one-third of the distance across. It is highly probable that High and Bear Lakes at one time formed one unbroken sheet of water, being connected around the south end of the sand ridge at (N).

In October, 1900, no water above 22 feet in depth was found in what was left of the lake and three-fourths of the remaining water area was less than 12 feet deep, while it was everywhere thickly turbid with the sediment of decaying algæ and other organic matter. On the south side between (P) and (O) are wooded hills rising 25 to 40 feet above the former lake level. The water adjoining these hills has been reduced to a narrow morass, 20 rods wide, bordered on the north by the former bed of the lake, the surface of which is gravel and sand. A large portion of the former water area opposite the shore between (O) and (Q) has become a marsh covered with cat-tails. On the west shore between (R) and (S) a ridge of sand, 10 rods wide and thickly covered with boulders, has been brought to the surface. Over this were the scattered remains of many fishes and shells. One of the accompanying illustrations shows this ridge and gives a good idea of the nature of the former bottom of this portion of the lake.

MARL.—No trace of marl was found by any of the bores put down on High Lake. Along the entire eastern shore between (K) and (N) the bottom, for 250 and more feet out, was of sand before the lake was lowered. Much of this former sand bottom is now dry land. The southeastern lobe and the shallow water adjoining the entire southern and western shores is underlain with muck from 10 to 18+ feet in depth. A tamarack swamp occupies much of the former shore between (K) and the section corners. But little tillable land was reclaimed by the draining of High Lake and it would be far better to fill up the ditch and allow its basin to refill than to leave it as it is now, a pest-breeding spot of muck and mud.

* Loc. cit., p. 27.

PLATE 9.

a

b

ILLUSTRATING RESULTS OF DRAINING OF HIGH LAKE, NOBLE COUNTY.

(a) Present beach on west side of lake, formerly covered with water; a portion of the kame or esker mentioned in text.

(b) Portion of esker island, and stretch of mud flat beyond; both formerly covered with water.

TIPPECANOE LAKE.

NOT A WORKABLE DEPOSIT.

This, the largest lake in Noble County, lies in sections 28, 29, 32 and 33 (33 north, 9 east), in the extreme southern part of the county. It has a length of nearly one and one-half miles and a width of over one-half a mile. As a rule the shores seem to show rather broad areas of shallow water, the width from shore being, however, rather variable. The shores of the lake are low, except upon the south, where a wooded bluff rises 25 to 40 feet above the water level. This and adjoining lakes form the extreme head-waters of Tippecanoe River, one of the most picturesque streams of Indiana.

Dr. P. H. Kirsch reports* the following fishes as having been taken in the lake:

Lepisosteus osseus (L.). Common Gar-pike.
Ameiurus nebulosus (Le S.). Common Bullhead.
Pimephales notatus (Raf.). Blunt-nosed Minnow.
Coregonus artedi sisco (Jor.). Cisco.
Zygonectes notatus (Raf.). Top Minnow.
Lucius vermiculatus (Le S.). Grass Pike.
Chænobryttus gulosus (Cuv. and Val.). War-mouth.
Lepomis pallidus (Mitch.). Blue-gill.
Micropterus salmoides (Lacépède). Large-mouthed Black Bass.
Perca flavescens (Mitch.). Ringed Perch; Yellow Perch.

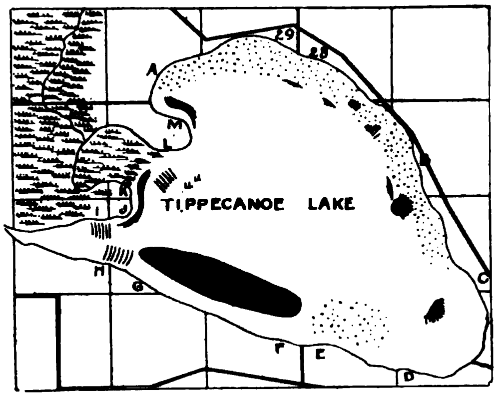


Fig. 33. Map of Tippecanoe Lake, Noble County, Ind.

MARL.—The marl deposits of Tippecanoe Lake are irregularly distributed. Along the east and northeast sides the shore tends to

* Bull. U. S. Fish Commission, 1894, p. 40.

show a hard sandy bottom of some width with marl in only a few places, and then generally in water eight or more feet deep. Off from (M) the marl extended below 16-foot drill in nine feet of water. Southeast of (L) beneath 12 feet of water only muck was found, though beneath eight feet of water near this eight feet of marl occurs. Off from (J) and (K) only muck having a depth of 13 feet and over occurs in shallow water, but out in seven to nine feet of water the bottom of marl could not be reached. Out from (H) the marl was thin, only four feet being found in seven feet of water. At the western end of the lake the water is shallow over a large area, running from three to 10 feet deep. Most of the drillings in this part of the lake found marl which in many cases extended to below 16 feet, but more often was less than eight feet thick. Along the western half of the south side there is a considerable area where the water is less than 10 feet deep and where all borings passed through marl to below 16 feet. Some marl was found in the southeast corner of the lake, but most of the drillings along the eastern end of the south side found a mud bottom. While the deeper waters of the lake are doubtless largely underlain with marl, the amount at present available in shallow water is too small to justify development.

WHITLEY COUNTY.

REFERENCES.—

1859.—Richard Owen, Geol. Reconn. of Ind., p. 216.

1891.—Dr. C. R. Dryer, Seventeenth Ann. Rep. Ind. Dep. Geol. and Nat. Resources, p. 160.

1899.—Frank Leverett, Water Supply and Irrigation Papers, U. S. Geol. Surv., No. 21, p. 47.

1899.—E. B. Williamson, Proc. Ind. Acad. Sci., p. 151.

Whitley County is bounded on the north by Noble County, on the east by Allen, on the south by Huntington and Wabash and on the west by Wabash and Kosciusko counties. It contains 10 civil townships, nine of which correspond to the congressional townships and contain 36 square miles each; the other, Etna, in the northwest corner, having but 12 square miles—a total of 338 in the county. The county is crossed by three railways. The Pittsburgh, Fort Wayne & Chicago passes from northwest to southeast through the central portion; the Eel River Division of the Wabash, from northeast to southwest diagonally across the county, and the New York, Chicago & St. Louis (Nickel Plate), from east to west through the northern part of the southern tier of townships. The surface of

the county lies between 787 and 948 feet above tide, the lowest point being near Collamer and the highest near Larwill. The elevation in feet above tide of the more important railway stations in the county is as follows: Churubusco, 887; Coesse, 850; Collamer, 787; Collins, 862; Columbia City, 838; Dunfee, 858; Larwill, 948; Peabody, 836; Taylors, 856; South Whitley, 813.

The entire area of the county is overlain with drift, the thickness of which is known in but two places, viz., at Columbia City, where it is 224 feet, and at Larwill, seven miles west, where it is 365 feet in thickness. That portion of the surface lying east and south of Eel River is flat or slightly rolling, being a part of the great level plain of east-central Indiana, though occasional knolls and ridges of drift, especially in Cleveland Township, give it some diversity. North and west of Eel River the surface is much more irregular and contains many deep, elongated valleys, with sharp, winding ridges intervening. The region drained by Blue River, comprising the northeastern third of the county, is less broken, but is still typically morainic in character.

The lakes of Whitley County are few in number and are found wholly in the northern tier of townships. Only eight have an area of more than 150 acres each. Of these seven were visited and are described in detail on the pages which follow. Five of the seven are largely underlain with marl, but only two of the deposits are deemed to be workable under present conditions. These two are distant from transportation facilities, so that some time must elapse before the marl will be utilized for cement making.

BLUE RIVER LAKE.

Large Deposit, Mostly Under Deep Water.

This lake lies two miles northwest of Churubusco, in sections 9, 10, 15 and 16 (32 north, 10 east), Smith Township. It is two miles or less from the Eel River Division of the Wabash Railway.

The lake is oblong in shape, narrower at the eastern end, about one and one-quarter miles long by one-half mile in average width, and has an area of about 420 acres. It has a very uniform depth of 40 to 55 feet. The area of shallow water is of medium width, rather broad on the east, south and west sides, and narrower on the north. The shores at most points are rather abrupt, the surrounding country being of a rolling type. The lake receives its waters from Upper Blue River, a small stream from Noble County, and from springs

along the sides and bottom of the lake. The outlet, Blue River, a tributary of Eel River, is at the west end, and only a few rods from the entrance of the inlet above mentioned.

Blue River Lake is well stocked with game and food fishes, the large-mouthed black bass, blue-gill, ringed perch and calico bass being abundant. The following is a list of the fishes taken in the lake in 1892, by the State Fish Commissioner, Mr. P. H. Kirsch:

LIST OF FISHES KNOWN TO OCCUR IN BLUE RIVER LAKE.

1. *Lepisosteus osseus* (L.). Common Gar-pike.
2. *Amia calva* L. Dogfish.
3. *Ameiurus natalis* (Le S.). Yellow Cat.
4. *Ameiurus nebulosus* (Le S.). Common Bullhead.
5. *Minytrema melanops* (Raf.). Striped Sucker.
6. *Notropis anogenus* Forbes. Small-chinned Minnow.
7. *Notemigonus chrysoleucus* (Mitch.). Golden Shiner.
8. *Coregonus artedi sisco* (Jordan). Cisco.
9. *Zygonectes notatus* (Raf.). Top Minnow.
10. *Lucius vermiculatus* (Le S.). Grass Pike.
11. *Pomoxis sparoides* (Lacépède). Calico Bass.
12. *Chænobryttus gulosus* (Cuv. and Valenc.). War-mouth.
13. *Lepomis cyanellus* Raf. Green Sunfish.
14. *Lepomis pallidus* (Mitch.). Blue-gill; Blue Sunfish.
15. *Lepomis gibbosus* (L.). Common Sunfish.
16. *Micropterus salmoides* (Lacépède). Large-mouthed Black Bass.
17. *Etheostoma eos* (Jor. and Cope.). Sunrise Darter.
18. *Etheostoma microperca* Jor. and Gilb. Least Darter.
19. *Perca flavescens* (Mitch.). Ringed Perch; Yellow Perch.

In his report on Whitley County, Dr. Dryer speaks of the midsummer vegetation about the shores of this lake as follows: "Aquatic vegetation in great variety and profusion furnishes a botanist's paradise. The shores are nearly surrounded by a broad belt of plants arranged in distinct zones, according to the depth of the water. On approaching the shore the first zone appears at depths between eight and six feet, and consists of the water-shield, *Brasenia purpurea* (Michx.); pondweeds or *Potomogeton*, species with filiform leaves being very abundant; several kinds of bladderwort or *Utricularia* and water millfoil, *Myriophyllum*. At a depth of four feet the yellow pond lily, *Nuphar advena*, covers the water with its leaves, the spaces between being filled with a dense mass of *Chara* covered with a mantle of duckweed or *Lemna*. Here navigation becomes difficult. At a depth of three feet the pickerel-weed, *Pontederia*

cordata L. appears with the water smartweed, *Polygonum amphibium.* At two feet the water passes gradually into a jungle of swamp loosestrife, *Decodon verticillatus* (L.); cat-tail, *Typha latifolia* L.; water-pepper, *Polygonum nodosum*; reed-grass, *Phragmites communis* Trin., and different species of willow, *Salix*, passable only by birds and reptiles. This lake is the only locality known to the writer in northeastern Indiana where the splendid American lotus, *Nelumbo lutea* (Willd.) occurs, and here it is as abundant as the white water lily, *Nymphæa odorata* Dryand. Its flowers are difficult to procure because they are gathered by numerous visitors as fast as they open, but the leaves, rolled up and rocking like a boat, or expanded into an orbicular shield twenty to thirty inches in diameter and flapping in the wind, present an interesting and attractive sight. The water of Blue River Lake in midsummer has the appearance of muddy coffee, and through the whole season teems with plant and animal life. Such a lake as this would repay a thorough and prolonged biological examination, and would furnish the naturalist with material enough for several years' study."*

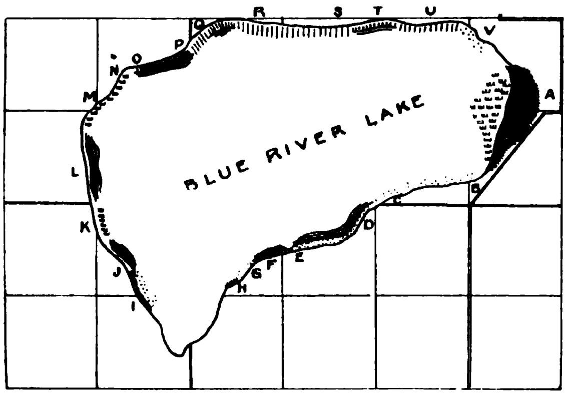


Fig. 34. Map of Blue River Lake, Whitley County, Ind.

MARL.—The distribution of the marl in Blue River Lake is very irregular. In places it extends back some distance from shore, while but a short distance away it is not found until deep water is reached. At (A) the bare marl extends back some distance from shore, 16 feet and more deep. Then it begins to be covered with sand, which increases in depth toward the bluff, the last drilling showing two feet of sand underlain by marl to below 16 feet. Out in the lake from shore, several tests in one foot or a little over of water showed over 15 feet of marl. In two feet of water the marl was only 11

* Loc. cit., p. 166.

feet deep with a blue mud bottom. Then the marl increases in depth again, but at the same time becomes mucky, and the tests in water from three to 16 feet deep showed only muck. How far the marl runs back under the bank can only be conjectured. At the east end of the south side of the lake, no marl was found, the bottom being sandy. Several attempts to find marl under the sand failed. From (D) to (E) the bottom is hard sand or blue mud for about 50 feet out from shore or in from five to eight feet of water, then for 25 feet, or in water from five to 15 feet deep, the marl is over 16 feet thick and of good quality. For a short distance, at (F), 25 feet from shore, the marl is beyond 16 feet deep in three feet of water. But diagonally out from this in six feet of water only blue mud is found. At (G) this mud bottom extends up to the shore, while at (H) the top of the mud is marly. At (I) the marl is one foot deep at the shore and the same out in one foot or a little over of water. In three feet of water and from there out the bottom is sandy. At (J) tests in water from two to five feet deep showed marl everywhere to below 16 feet. Just north of this only muck was struck, then the marl sets in again, the bottom not being reached in from one foot to seven feet of water. In the northwest corner of the lake only muck was found. Then from (O) to (P) the marl occurs again, running from one foot deep in six inches of water to beyond reach of drill at the six-foot water-line. East of this it is shallow again, only one foot of marl being found in four feet of water. From (R) to (V) the marl is variable, often being absent close to shore and in places is not over one foot thick in 10 feet of water; but generally the marl is of good depth in six to 10 feet of water.

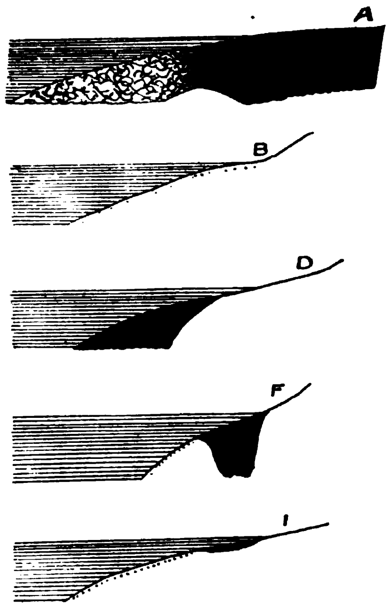


Fig. 35. Cross sections showing character of deposits at various points along shore of Blue River Lake, Whitley County, Ind.

The tests show that a large body of deep water marl occurs in the lake which may some day become available. The amount beneath shallow water is entirely too small to be of use at the present time.

ROUND, CEDAR AND SHRINER LAKES.

Not a Workable Deposit.

These lakes lie close together in sections 1, 2, 11 and 12 (32 north, 9 east), Thorn Creek Township. They are connected by natural or artificial channels and hence will be treated under one general heading. The railway nearest them is the Eel River Division of the Wabash, distant about three and one-half miles to the southeast.

ROUND LAKE.

This lake, which receives its waters from the other two and from the drainage of the neighboring woods and fields, has a length of seven-eighths of a mile and a maximum width of one-half a mile. Its shores on the north and east are rather thickly wooded and rise 20 to 30 feet above the water. The south shore is lower and bordered with cultivated fields. A long bay filled with aquatic vegetation extends out to the northwest. From it an artificial channel connects Round Lake with Shriner Lake. The inlet from Cedar Lake is through a marsh grown up with cat-tail flag, *Typha latifolia* L., button-bush, *Cephalanthus occidentalis* L., swamp loosestrife, *Decodon verticillatus* (L.), and a variety of other aquatic plants, with occasional stretches of open water. It enters the north side of Round Lake, while the outlet, Thorn Creek, a tributary of Blue River, leaves the south side. Thorn Creek has been dredged for some distance, thus materially lowering the water area of the lake. As a result, a number of long points project out under the water and there is a large area of shallow water in the western third of its basin. "Lowering the lake five feet more will fill it with sand bars or even reduce it to a number of ponds. An extensive tract near the head of Thorn Creek, which five years ago was a swamp, is now under cultivation. Among the farmers of the neighborhood the practice is common of planting artichoke among the spatterdock where the lowering of the lake has exposed the land. In the fall this is turned over to hogs and their persistent rooting in the soft earth pulverizes and dries the soil most effectually."*

In October, 1900, a series of soundings, about 10 rods apart, beginning at the eastern edge of shallow water on the west side and running east, a little south of the middle of the lake, showed the depth of the water to be respectively: 18, 12, 28, 25, 26, 32 and 17

* Williamson, loc. cit., p. 153.

feet. Another line running across from (M) to (C) gave 17, 22, 38, 48, 51, 54, 57 and 32 feet.

The vegetation about Round Lake is very rank. The spatterdock, *Nuphar advena* R. Bv., is very common, filling most of the bays and bordering the shores in many places. In the region of the second sounding, in the first series given above, a species of pondweed* was abundant, its fruiting head above the surface, its roots in the marl 12 feet below. Other species of pondweed are very common. Mr. C. C. Deam, of Bluffton, has found the reversed bladderwort, *Utricularia resupinata* Greene, growing along the western shore. The greater bladderwort, *U. vulgaris* L., is abundant, and eel grass, *Vallisneria spiralis* L., hornwort, *Ceratophyllum demersum* L., several species of water-millfoil, *Myriophyllum*, and the stiff white water crowfoot, *Batrachium tricophyllum* (Chaix.), cover the bottom of the more shallow portions of the lake.

The number of fishes in Round Lake is greater than in either of its neighbors, as is evinced by the following list of those taken in the three lakes in 1892 by Mr. Kirsch:

LIST OF FISHES KNOWN TO OCCUR IN ROUND, CEDAR AND SHRINER LAKES.†

1. *Lepisosteus osseus* (L.). Common Gar-pike.
2. *Ameiurus natalis* (Le S.). Yellow Cat.
3. *Ameiurus nebulosus* (Le S.). Common Bullhead.
4. *Catostomus teres* (Mitch.). Small-scaled Sucker; Black Sucker. Round Lake only.
5. *Erimyzon sucetta* (Lacépède). Chub Sucker; Sweet Sucker. Round Lake only.
6. *Minytrema melanops* (Raf.). Striped Sucker. Round Lake only.
7. *Pimephales notatus* (Raf.). Blunt-nosed Minnow.
8. *Notropis cayuga* Meek. Meek's Minnow.
9. *Notropis heterodon* (Cope). Variable-toothed Minnow.
10. *Notropis megalops* (Raf.). Common Shiner. Cedar and Round lakes.
11. *Hybopsis amblops* (Raf.). Silver Chub.
12. *Coregonus artedi sisco* (Jor.). Cisco. Shriner and Cedar lakes.
13. *Zygonectes notatus* (Raf.). Top Minnow. Shriner and Cedar lakes.

*This is the white-stemmed pondweed, *Potamogeton prælongus* Wulf. Another species very common in shallow water, where it formed thick beds on the bottom, was *P. robbinsii* Oakes. It grows but a foot or two high, and when the water is agitated the leaves spread out so that the whole plant resembles a fern. Both stem and leaves then wave gently to and fro in graceful motion.

† Where the species occurs in all three of the lakes no locality is given. Where in but one or two of them, they are mentioned specifically.

14. *Lucius vermiculatus* (Le S.). Grass Pike; Little Pickerel.
15. *Labidesthes sicculus* Cope. Brook Silverside; Smelt.
16. *Pomoxis sparoides* (Lacépède). Calico Bass.
17. *Chænobryttus gulosus* (Cuv. and Valenc.). Warmouth.
18. *Lepomis cyanellus* Raf. Green Sunfish. Round Lake only.
19. *Lepomis pallidus* (Mitch.). Blue-gill; Blue Sunfish.
20. *Lepomis euryorus* McKay. Broad-eared Sunfish. Cedar and Shriner lakes.
21. *Lepomis heros* (Baird and Girard). Chain-sided Sunfish. Round Lake only.
22. *Lepomis gibbosus* (L.). Common Sunfish.
23. *Micropterus salmoides* (Lacépède). Large-mouthed Black Bass.
24. *Etheostoma nigrum* (Raf.). • Johnny Darter.
25. *Etheostoma eos* (Jor. and Cope.). Sunrise Darter.
26. *Etheostoma microperca* Jor. and Gilb. Least Darter. Round Lake only.
27. *Perca flavescens* (Mitch.) Ringed Perch; Yellow Perch.

MARL.—On the two bars indicated at (G) and (I) the water is shallow, a foot or less deep, and the marl from one to four feet in depth, while in two-and-a-half-foot water it thickens to seven feet. At the edge of deep water opposite (I) the marl had decreased to six feet and was underlain with a stiff, blue mud. In 12 feet of water it was six feet thick and underlain with gravel. Along the south shore between (J) and (K) the shallow water area, for the most part, overlies a good quality of marl 12+ feet in thickness. Near (M) in three feet of water it was 16+ feet thick but dark in color. At (A), across the lake, the same conditions exist, and at (B) there is too much muck to render the deposit of value. Good marl sets in again to the westward, and is everywhere 15+ feet thick in three feet of water. The shallow water area west of (C) widens greatly and is in most places, except within five rods of shore, underlain with marl below reach of 18-foot drill, though the water was seldom over 18 inches in depth. Close to shore the thickness of the marl is variable, running from three to 11 feet. The tests show that probably one-half of the area of the lake is underlain with marl. It is, however, variable in quality, much of that along the east end merging gradually into muck.

CEDAR LAKE.

This lake lies just northwest of Round Lake and empties into the latter through a broad, weedy channel. Cedar Lake is nearly divided into two unequal lobes, at the crossing of the north-south section

line. The upper and larger lobe is about one mile long by one-quarter of a mile wide, with its main axis lying northwest and southeast. From its western side a short arm, now choked with vegetation, protrudes. The center of its basin shows a depth of water ranging from 45 to 79 feet. The lower lobe is but about one-third the size of the upper and is quite shallow. The shores of the entire lake are covered with underbrush, due to the fact that its level was raised by a dam at the same time that that of Shriner Lake was lowered. The shallow water area thus gained in the lower lobe is in part filled with muck and bears much aquatic vegetation, the spatterdock or yellow water lily being especially abundant. There are also many tree trunks and fallen limbs near the shore, which detract much from the original natural beauty of the lake.

MARL.—At most points around the lake the marl is shallow within the six-foot water line. Thus at (A) no marl is found in one or two feet of water, but in three feet or more of water the marl extends to below 16 feet. From (B) to (C) the marl is only six feet deep in seven feet of water, four feet in four feet of water, etc., the shallow water area being very narrow. From (D) to (E) the marl is deeper, being over 12 feet deep in four feet of water, and to below reach of drill at all depths beyond. From (E) to (G) some of the depths of marl found were as follows:

Water 4 feet—marl 8 inches to 3 feet.
Water 6 feet—marl 3 feet.
Water 7 feet—marl 7 feet.
Water 8 feet—marl 7 feet.

From (H) to (K) the marl is somewhat deeper, just about reaching 10 feet on the six-foot water line and extending below pole in all deeper water. At (L) only muck was found. Off the point at (M) the marl is over 15 feet deep in one foot of water at 75 feet from shore. From (N) to (P) in four and five feet of water, it runs from four to 10 feet in depth. Around most of the lake the area of shallow water is very narrow.

SHRINER LAKE.

This is one of the prettiest bodies of water in Indiana. Long and narrow, it lies like a priceless emerald of palest green, hidden and guarded by the surrounding hills. Its basin is in shape a deep trough or V, somewhat curved, one and one-quarter miles long by less than one-quarter mile wide in average width. In most places the water is shallow for only a few yards, or even feet from the shore line,

when the bottom suddenly descends at a sharp angle to a depth, in some places, of 65 or more feet. A small stream, dry most of the year, enters the lake at its southwestern corner; but springs are almost the entire source of water supply, hence the clearness and purity of its depths. Back from the water line the shores rise in low bluffs, which are covered with oak, maple and beech timber. A few sycamores and cotton-woods grow near the water's edge. Around the northern lobe of the lake the shores have, for the most part, been cleared, and are cultivated in places, within 75 feet of the water's edge.

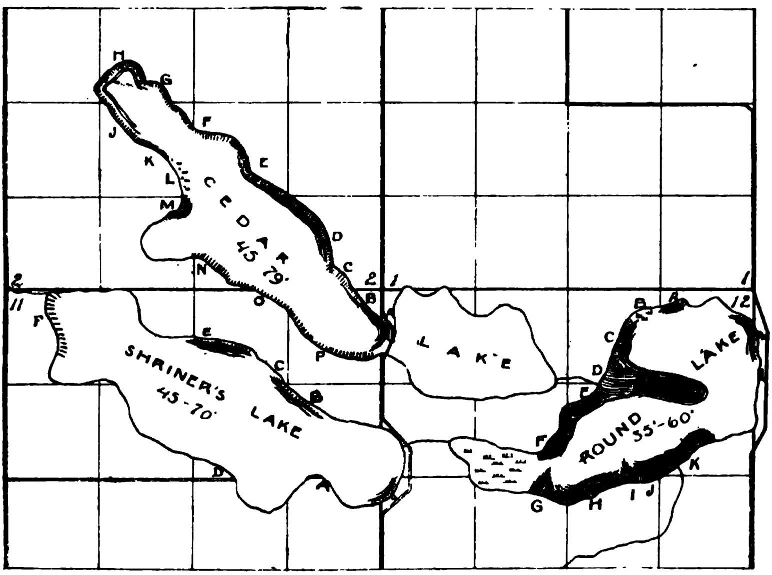


Fig. 36. Map of Cedar, Round and Shriner Lakes, Whitley County, Ind.

A number of soundings were taken in Shriner Lake on October 3d, 1900. In the southeast corner, at the boat landing, the water was six feet deep 20 feet from shore; 30 feet out it was 18 feet, and 100 feet out, 42 feet in depth. Forty rods west, on the south shore at (A), the shallow water area is less than 20 feet wide, then dips down at an angle greater than that of a steep house roof. The bottom, where it could be reached, was of a very tenacious blue mud, from which the auger, when sunk with difficulty about a foot, could hardly be removed. Ten feet from shore the water was eight feet deep. Three oar-strokes out it was 21 feet and 70 feet out was 32 feet. A line of soundings 50 feet apart from here across to (B) found the following depths: 45, 63, 65, 40, 27 and 8 feet, the last a

boat's length from the north shore. Here the bottom was of marl six feet thick, with gravel beneath. At the bend, where the basin of the lake turns northward, a row of soundings from (C) to (D), 75 feet apart, resulted as follows: 48, 52, 50, 66, 60 and 34 feet. At this point the west shore is of gravel or sand, with but little vegetation. Sixty feet back from the water the wooded gravel hills rise 25 feet or more. Rowing 40 rods north along the gravelly west shore, another line, 10 oar-strokes apart, from east to west, showed 28, 51, 66, 62 and 26 feet. The shore on the east is here bordered by a marshy area, three to six rods wide, in which rushes, spatterdock and the green arrow-arum, *Peltandra virginica* (L.), flourish in profusion. The muck is here 12 feet deep in three-foot water, but at the water's edge the bottom is of a stiff blue mud. Just above this the lake narrows somewhat and then expands into a wider basin which comprises about one-quarter its area. Soundings near the center of this lobe showed the depth to range from 32 to 46 feet. Along the west shore of this basin the three-foot water line is underlain with 12 feet or more of muck, with gravel beneath.

In Shriner Lake and its neighbors, Round and Cedar lakes, are found growing in profusion many species of water-loving plants. Mr. C. C. Deam, of Bluffton, has taken there in August and September, the following species, all of which are aquatic, i. e., grow partly or wholly in the water:

LIST OF PLANTS GROWING IN ROUND, CEDAR AND SHRINER LAKES.

Typha latifolia L. Broad-leaved Cat-tail.
Potomogeton, four species. Pondweeds.
Sagittaria rigidi Pursh. Stiff Arrow-head.
Zizania aquatica L. Wild Rice.
Homalocenchrus oryzoides (L.). Rice Cut-grass.
Cyperus engelmanni Steud. Engelmann's Sedge.
Cyperus rivularis Kunth. River Sedge.
Dulichium arundinaceum (L.).
Eleocharis interstincta (Vahl.). Knotted Spike-rush.
Eleocharis mutata (L.). Quadrangular Spike-rush.
Scirpus americanus Pers. Chairmaker's Rush.
Scirpus atrovirens Muhl. Dark-green Bulrush.
Scirpus lacustris L. Great Bulrush; Mat Rush.
Scirpus lineatus Michx. Reddish Bulrush.
Rhynchospora glomerata (L.).
Cladium mariscoides (Muhl.). Twig-rush.
Carex lupuliformis Sartwell.

Carex comosa Boott. Bristly Sedge.
Eriocaulon septangulare With. Seven-angled Pipewort.
Pontederia cordata L. Pickerel-weed.
Juncus canadensis Gay. Canada Rush.
Rumex verticillatus L. Swamp Dock.
Polygonum incarnatum Ell. Slender Pink Smartweed.
Polygonum punctatum Ell. Water Smartweed.
Polygonum sagittatum L. Arrow-leaved Tear-thumb.
Brasenia purpurea (Michx.). Water-shield.
Nymphæa advena Soland. Large Yellow Pond Lily.
Castalia odorata (Dryand). White Water Lily.
Batrachium trichophyllum (Chaix.). Stiff White Water Crowfoot.
Decodon verticillatus (L.). Swamp Loosestrife.
Myriophyllum, one species. Water Millfoil.
Cicuta bulbifera L. Bulb-bearing Water-hemlock.
Cicuta maculata L. Water-hemlock.
Lycopus rubellus Moench. Water Hoarhound.
Mentha piperita L. Peppermint.
Gerardia paupercula (Gray). Small-flowered Gerardia.
Utricularia resupinata Greene. Reversed Bladderwort.
Utricularia vulgaris L. Greater Bladderwort.
Cephalanthus occidentalis L. Button-bush; Globe-flower.
Lobelia cardinalis L. Cardinal Flower.
Bidens beckii Torry Water Marigold.
Bidens trichosperma (Michx.). Tall Tickseed Sunflower.

MARL.—On account of its deep shelving basin but little marl occurs around the margin of Shriner Lake. In the southeastern end near the boat landing there is a deposit six feet thick in two feet of water, and 12+ feet thick in six feet of water, but it is dark in color. Between (B) and (C) a better quality is found which is six feet thick in eight feet of water, but the bottom dips so rapidly that but little of it is available. Opposite (E), about half way the length of the east shore, there is an acre or two of shallow water, in which the marl is 15 feet thick in two-foot water and eight feet thick in one-foot water, with blue mud beneath. In the northwestern corner, at (F), there is a small area with marl bottom nine to 12 feet in thickness, in two to five feet of water. At all other points examined the bottom was of gravel, sand or muck.

There is, without doubt, quite an extensive deposit of marl beneath the deep water areas of Cedar and Round lakes, but that in Shriner Lake is evidently limited in extent. The deposit beneath the three lakes, considered as a whole, is not believed to be of sufficient importance to attract capital for cement making.

CROOKED LAKE.

Workable Deposit, Partly Under Deep Water.

The east end of Crooked Lake is only a little over a quarter of a mile from the west ends of Cedar and Shriner lakes, but is separated from them by the water-shed or divide between the basins of Eel and Tippecanoe rivers. This divide is a ridge about a fourth of a mile wide and 25 or 30 feet high. The lake lies in section 33 (33 north, 9 east), Noble Township, Noble County, and sections 3 and 4 (32 north, 9 east), Thorn Creek Township, Whitley County. It is

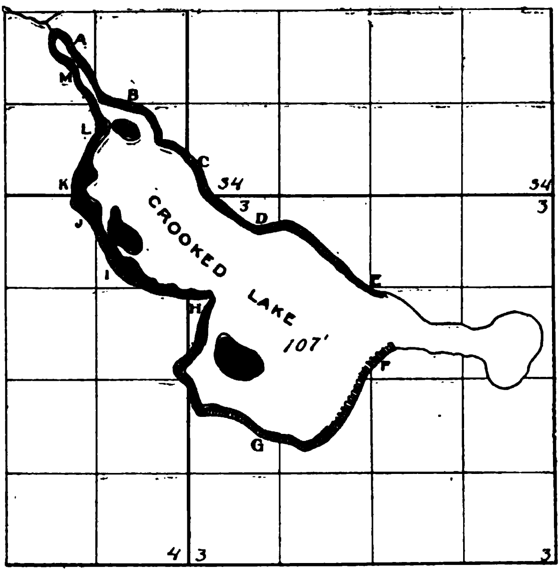


Fig. 37. Map of Crooked Lake, Whitley County, Ind.

very irregular in shape, as it grows very narrow at each end, while a prominent point from the southwest partly divides the main body into two irregular lobes. In size it is about one and one-quarter miles long with a width varying from a few rods to over half a mile, its main axis lying southeast and northwest.

The basin of Crooked Lake is very deep, a sounding of 107 feet having been taken near its center. Two submerged bars and a low island indicate a considerable area of fairly shallow water. The shallow water along the shore is generally narrow on the east side and around much of the eastern part of the main body of the lake. Along the western shore of the northwestern basin the shallow water

bench is very irregular but with a good average breadth over the most of which the water is only a foot or less deep. The banks around the lake rise rather abruptly 20 to 30 feet, with rolling ground back from their crest.

The lake is well stocked with fish, among the larger of which may be mentioned the long-nosed gar-pike, cisco or lake herring, grass-pike, calico bass, blue-gill, large-mouthed black bass and ringed perch. The lake forms the headwaters of the Tippecanoe River which, by a very circuitous course, finds its way into the Wabash near Lafayette.

Marl.—Tests near the outlet of the lake at (A) showed three feet of marl in one foot of water, over 14 feet in two feet of water, and bottom not reached at greater depths. Toward (B) the marl in two feet of water ranged from eight to over 14 feet. The small shoal at the entrance to the western tongue has only about one foot of water over it and more than 15 feet of marl beneath. From (C) to (D) the marl is irregular, the three-foot water line varying from 20 to 100 feet from shore, and the marl from four feet to 13+ feet, the best being near the bend in shore, about half way between the two points. From (D) to (E) the shallow water is very narrow, in places the six-foot water line coming within 20 feet of shore. The marl runs from fair to good in thickness. At (F) the marl is four feet thick in four feet of water and five feet in eight feet of water, 100 feet from shore. Towards (G) the marl gets thicker, until 10 feet deep in two feet of water. On the shoal between (G) and (H) it extends to below 16 feet. At (H) the marl is mucky. From (H) to (M) the marl extends to below 16 feet at every point tested, including the island. Much of the shallow water area is broad and has only a foot or less of water over it, so that a large area of available marl is present along this shore. There is no doubt but that the greater part, if not all, of the deep water of this lake is underlain with a thick marl deposit. By lowering the water five to eight feet, a sufficient supply could be added to that already available to last a large cement factory for many years. We would not advise such a course, however, as under its present conditions, the lake is far more valuable to mankind at large than it would be were much of its present water area turned into mud flats. Then only a few manufacturers would derive a benefit from its marshy shores. Now the angler and the sportsman from far and wide can seek health and pleasure o'er its watery expanse.

LOON LAKE.

Workable Deposit, Partly Under Deep Water.

Two years ago this was one of the most beautiful sheets of water in northern Indiana. To-day it is a mud hole—a pond surrounded by wide margins of ill-smelling muck and marl. Then its clear waters rippled against the shelving banks almost at the very thresholds of the many summer cottages in the beautiful wooded grove on the south and east shores. Now a barren waste of gravelly or marly beach, 85 paces wide and in part o'ergrown with noisome weeds, intervenes between the cottages and the edge of the water, while the latter is not over two feet deep for 10 rods or more farther out. There are weeds enough on earth and places sufficient for their growth without changing a clear watery expense, like that formerly existing here, into a barren, weed producing waste. Yet the average human, who sees no beauty in such spots as was Loon Lake—who is possessed only of the desire to conquer and hold in thralldom more of the acres of our mother earth, goes on with his dredging and his ditching, and will so continue until all of nature's beauty spots are gone, and only dreary weed patches and cultivated fields remain.

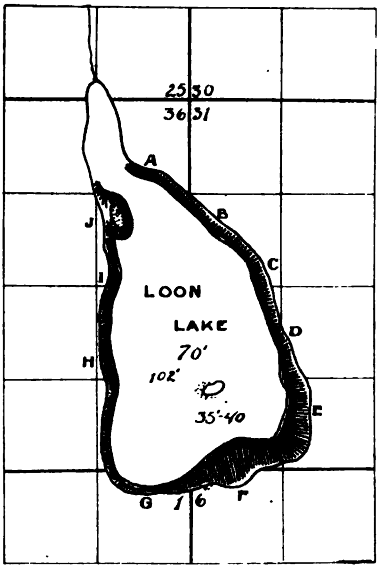


Fig. 38. Map of Loon Lake, Whitley County, Ind.

The basin of Loon Lake lies nine miles northwest of Columbia City, and is partly in Noble and partly in Whitley County. That portion in Noble County lies in section 31 (33 north, 9 east), Noble Township. That part in Whitley County lies in section 36 (33 north, 8 east), Etna Township; section 1 (32 north, 8 east), Troy Township, and section 6 (32 north, 9 east), Thorn Creek Township. It is roughly bottle-shaped with a short neck to the north and has a length northwest and southeast of one and one-eighth miles and a width of one-half mile. Before draining the water was very clear, so that objects at the bottom of 30-foot water could be plainly seen. The maximum depth was 102 feet, just northwest of a small but pretty

island near the southern shore. Between this island and the shore to the south the deeper water ranged from 35 to 40 feet, while the main body of water north of the island had an average depth of 70 feet. The lake was fed by the overflow of Old and New lakes, each with an area of about 60 acres, and lying respectively one-half mile to the west and southwest. Numerous springs also welled up from its bottom, their waters adding to the clearness of its contents. Its outlet joined with those of Tippecanoe and Crooked lakes to form a tributary of the Tippecanoe River. Since draining, in the spring of 1900, the depth of water in Loon Lake has decreased 12 feet, leaving a wide margin of the basin bare, and greatly increasing the shallow water area.

The lake is well stocked with food and game fishes, the following 15 species having been taken in one-half day by Prof. P. H. Kirsch during his investigations in 1892:

LIST OF FISHES KNOWN TO OCCUR IN LOON LAKE.

1. *Lepisosteus osseus* (L.). Common Gar-pike.
2. *Ameiurus nebulosus* (Le S.). Common Bullhead.
3. *Pimephales notatus* (Raf.). Blunt-nosed Minnow.
4. *Notropis cayuga* Meek. Meek's Minnow.
5. *Notropis heterodon* Cope. Variable-toothed Minnow.
6. *Zygonectes notatus* (Raf.). Top Minnow.
7. *Lucius vermiculatus* (Le S.). Grass Pike.
8. *Labidesthes sicculus* Cope. Brook Silverside.
9. *Chænobryttus gulosus* (Cuv. and Valenc.). War-mouth.
10. *Lepomis pallidus* (Mitch.). Blue-gill; Blue Sunfish.
11. *Lepomis megalotus* (Raf.). Long-eared Sunfish.
12. *Lepomis gibbosus* (L.). Common Sunfish.
13. *Micropterus salmoides* (Lacépède). Large-mouthed Black Bass.
14. *Etheostoma caprodes* (Raf.). Log Perch; Hogfish.
15. *Perca flavescens* (Mitch.). Ringed Perch; Yellow Perch.

MARL.—The investigation of the marl resources of Loon Lake was made before the draining took place and the conditions then found are now greatly modified. From (A) to (D) the conditions are much the same; the marl, which is thin or wanting close to shore, rapidly increasing in depth until in four or five feet of water it extends to below 16 feet from the surface. The line of six-foot water runs from 75 feet to 100 feet from shore. Toward (E) the shallow water area gets broader, and tests near shore show sand over the marl. Thus at 30 feet from shore in two feet of water there is found

one foot of sand and seven feet of marl. In three feet of water the marl is over 13 feet thick. Going toward (F) the marl is not so deep, drillings in three feet of water showing from three to 12 feet of marl, while one drilling in four feet of water showed only 10 feet. In deeper water the marl is beyond end of drill. The lake bottom around the island appears to be all gravel and a gravel bar covered with small boulders extends some distance west of the island. Along the west shore much the same conditions as on the east shore prevail, until toward the north end, where a sand and mud shoal occurs. A stop of less than a quarter of an hour was made on the south shore of the lake in October, 1900, while enroute to a station on the B. & O. Railway. There was no time for tests with auger. Along this shore the marl sets in and forms the surface of the drained area 120 feet out from the former margin. Over a wide area along the east shore it also forms the surface. The 120 or more acres in Old and New lakes, one-half mile distant, are reported to be wholly underlain with a good quality of marl. There is sufficient in the three lakes, or for that matter in Loon Lake alone, to attract the attention of capital for manufacturing purposes.

The quality of the Loon Lake marl, based upon chemical analysis, is fair only. In appearance it is white enough, and it is more than probable that samples carefully taken from below the surface with a spade will show better, as it is almost impossible to avoid mixing other substances with it when brought up from beneath water by the auger. An analysis of an average of a number of samples so obtained resulted as follows:

Analysis of Marl From Loon Lake.

Calcium carbonate ($CaCo_3$)	82.07
Magnesium carbonate ($MgCo_3$)	2.63
Calcium sulphate ($CaSo_4$)	.22
Ferric oxide (Fe_2O_3)	.42
Alumina (Al_2O_3)	.41
Insoluble inorganic matter (silica, etc.)	5.95
Organic matter	6.71
Total	98.41

PLATE 10.

a

(a) Long arm of Crooked Lake, Steuben County, nearly choked with aquatic vegetation. (See page 84.)

(b) Showing dense character of vegetation growing on drained marsh north of West Cedar Lake, Whitley County. Tamarack grove in the background.

CEDAR LAKE.

Not a Workable Deposit.

This lake lies in sections 10 and 11 (32 north, 8 east), Troy Township, about eight miles northwest of Columbia City and three miles southwest of Loon Lake. It occupies a valley 25 to 40 feet lower than the surrounding country. The original water area of about 150 acres has been lowered 10 feet by a ditch and water now covers only about 110 acres. For this reason the shallow water area around the margin is very narrow, and there are wide beaches of sand and muck which were formerly covered with water. The main body of the lake, comprising more than three-fourths of its southern area, is quadrangular in shape with narrow bays extending out some distance from the southeast and southwest corners. From the northeast corner of this main body the north shore runs 25 rods west, then turns north to form the narrow northern lobe of the lake which has its longer axis lying northwest and southeast.

On the south half of the east shore the gravelly beach rises gently into a level meadow about 25 rods wide, which intervenes between the lake and a wooded ridge. The shore is bordered with the rushes *Scirpus americanus* Pers. and *S. lacustris* L., but the bottom of the lake shelves off rapidly, 14 feet of water being found 50 feet from the margin. The northern half of the east shore is low and mucky, many soft maple trees (*Acer saccharinum* L.) fringing the woods which lie beyond. The north and northwest shores are bordered by an extensive morass, over which the elbow brush or button bush, *Cephalanthus occidentalis* L., the winter berry, *Ilex verticillata* (L.), the swamp loosestrife, *Decodon verticillatus* (L.), and several species of dwarf willows and other mud-loving shrubs, grow in such profusion that one can scarcely force his way among them. Beyond these shrubs is a large tamarack swamp. The margin of this portion of the lake is widely bordered with cat-tails and spatterdock, and the water evidently formerly covered a large area to the northwest. The west and south shores are, for the most part, low, with mucky margins. Only at one place, on the south side of a point of land which extends out from the north half of the west shore does a gravelly margin occur. Here numerous boulders cover the surface for some distance back from the water's edge.

The water of Cedar Lake is turbid and contains enormous quantities of the lower forms of vegetable organisms. At places, especially over most of the northern lobe, the wake of the moving boat was bordered by a plainly visible line of green slime composed of

unicellular plants. A row of soundings about 10 rods apart, taken from east to west and 15 rods south of the north shore of the main body, showed the following depths: 12, 15, 24, 26 and 32 feet. Over the greater portion of the north lobe the depth ranges from 12 to 18. feet. A line of soundings from north to south, 25 oar-strokes apart, along the eastern margin of the western third of the main body of water found the depths to be respectively 25, 38, 44, 20, 24, 18 and 40 feet. Another line from west to east, along the northern margin of the southern third of the same body gave 40, 71, 81, 72 and 28 feet. Two soundings near the center gave 83 and 87 feet, the latter being the maximum depth found.

Besides the plants above mentioned the eel grass, *Vallisneria spiralis* L., the white water lily, *Castalia odorata* (Dryand), the three-squared rush, *Scirpus americanus* Pers., and the green arrow-arum, *Peltandra virginica* (L.), occur in the narrow shallow water area, around the main body of the lake, while the duckweeds, *Spirodela polyrhiza* (L.) and *Lemna minor* L., and the ditch-moss, *Philotria canadensis* (Michx.), flourish in profusion in the more shallow northern lobe. Muskrat houses were plentiful and their principal winter food—the fresh-water bivalves—were abundant in individuals but not in species, only *Anodonta grandis* Say, *Unio luteolus* Lamarck and *U. subrostratus* Say being found. Where the rats feed upon the thin shelled *Anodontas* one valve is always broken, but the valves of the thicker shelled *Unios* are left intact. How the animal opens them thus is, as yet, an unsolved problem.

The outlet of Cedar Lake leaves the southwest corner, and flows westward, uniting with that from Robinson Lake on the west line of the county, then northward into Ridinger Lake, Kosciusko County, and finally forms a tributary of the Tippecanoe River.

MARL.—But little marl was found in Cedar Lake. It is fed mainly by small streams which enter from the north, and by the drainage of the surrounding fields, hence the conditions for marl deposition are poor. Near the southeast corner a shallow water area 15 rods wide borders the south shore. Beneath this, in two to five feet of water, six feet of a fairly good quality of marl occurs beneath three feet of a mixture of muck and marl. The narrow shallow water area around the remainder of the lake was everywhere underlain with muck 12+ to 18+ feet in thickness according to the depth of the water, except at two points on the north half of the east shore where a poor quality of marl, 12 feet thick, occurs in four-foot water 75 feet from shore. The marl is here underlain with a stiff blue mud, which could not be penetrated with the auger.

ELKHART COUNTY.

References.—

1859.—Richard Owen, Geol. Reconn. of Ind., p. 198.

1873.—G. M. Levette, Fifth Ann. Rep. Geol. Surv. of Ind., p. 451.

1899.—Frank Leverett, Water Supply and Irrigation Papers, No. 21, U. S. Geol. Surv., p. 23.

This county is bounded on the north by the State of Michigan, on the east by Lagrange and Noble counties, on the south by Kosciusko, and on the west by Marshall and St. Joseph. It is quadrilateral in outline and contains an area of 465 square miles.

The county is well supplied with railways. Three divisions of the Lake Shore & Michigan Southern traverse its bounds, while the Michigan Division of the "Big Four" and the Chicago Division of the Wabash pass entirely through it, the former in a north and south direction, the latter east and west along the north border of the southern tier of townships. The Baltimore & Ohio also cuts across the southeastern corner.

The St. Joseph River enters the county from Michigan, about six miles west of the northeast corner and flows in a southwest course into St. Joseph County. At Elkhart it receives its principal tributary, the Elkhart River, which drains the southeastern portion of the county. Both the St. Joseph and the Elkhart are dammed in numerous places, and furnish cheap and excellent water power for many extensive factories, especially at Goshen and Elkhart.

In common with all the counties in which the lakes occur, the surface of Elkhart is wholly covered with drift, the thickness of which is known at three points, viz., Elkhart, Goshen and New Paris, where it is respectively 122, 162 and 90 feet. The surface of this drift is more level than in the counties to the east and south, an area of about 200 square miles in the northwestern and southeastern parts of the county being composed of extensive gravel plains. The uplands consist of till plains, with an area of 125 square miles, in the southwest part of the county, and of morainic belts, more broken, in the southern and western portions. The elevation in feet above tide of some of the more important railway stations in the county is as follows: Bristol, 783; Dunlaps, 747; Elkhart, 725 to 755; Goshen, 796; Millersburg, 885; New Paris, 813; Vistula, 808. The gravel plains in general are below the 800-foot level. The uplands are mainly between 800 and 900 feet above tide, though several of the higher points rise above 900 feet.

The lakes of Elkhart County are few in number and small in size, and are, with one or two minor exceptions, confined to the civil townships of Osolo and Washington, adjacent to the Michigan line.

SIMONTON, MUD AND COOLEY LAKES.

Workable Deposit.

The former beds of these lakes occupy parts of sections 13, 14, 15, 16 and 17 (38 north, 5 east), Osolo Township. They lie in an east and west line with their northern borders within one-half to three-fourths of a mile of the Michigan boundary. Simonton Lake is the only one of these which at present contains a large water area, the other two having been drained. On account of their proximity, the three are treated under one heading.

SIMONTON LAKE.

This lake lies about three miles north of Elkhart and not far from the Michigan line. Its longer axis is east and west and it has

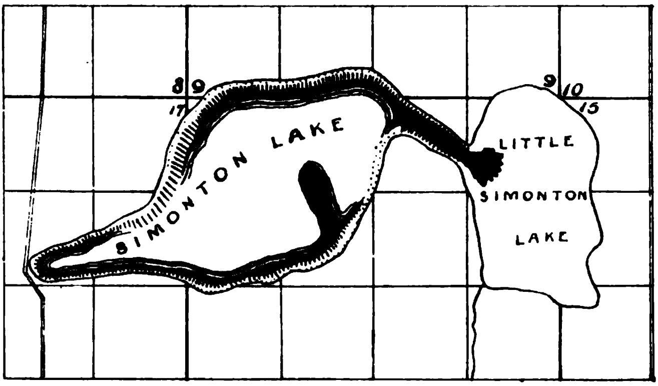


Fig. 39. Map of Simonton Lake, Elkhart County, Ind.

a length of one and one-half miles and width of over one-half mile. A large tongue of land from the south, jutting out a little east of the center, divides the lake into two unequal parts. When visited in the fall of 1899, the eastern or smaller of these was nearly dry, being in the condition of a marsh with open water channels too shallow for a boat. This part is sometimes known as "Little Simonton." The main body of the lake has shores with a fairly rapid de-

scent. Some shallow water (four to five feet) exists just east of the center of the main part of the lake, but the greater part of its area runs from six to 15 feet in depth. The outlet flows southward into the St. Joseph River.

MARL.—Marl is found all around this lake except from the north end of the dividing tongue of land to the boathouse on the southwest corner. As a rule the marl runs out a short distance from the shore but quickly attains a good thickness, which is maintained out to deep water. Little Simonton Lake was in the main inaccessible; tests made in it as far as it could be entered from the west showed 16 feet of marl. In quality the marl appeared unusually white and good, and as tested by the drill it seemed much more firm than the average deposit.

MUD LAKE.

Before draining, the water area of this lake was about a mile long by three-quarters of a mile wide. The lake is now a vast marsh, the water area having been reduced to about 15 acres which is a mud hole, the water averaging about three feet in depth. In general the surface is muck, which varies in thickness from one to four feet. Peat was found in but two places, between the muck and marl. Marsh grasses of various kinds formed the prevailing vegetation. Around the border of the remaining water were many cat-tails and rushes. The remains of many large bivalve shells, mainly *Anodonta grandis* Say, were scattered about the surface. The shells of one or two species of *Planorbis* were also very abundant.

The outlet of Mud Lake formerly flowed south and united with that of Heaton Lake, which lies about one mile to the southeast, to form a tributary of the St. Joseph River.

COOLEY LAKE.

The greater portion of the former area of this lake is now a quagmire over which no man can pass in the summer season, for he can not push a boat through the cat-tails, spatterdock and other aquatic vegetation, and if he attempted to wade he would sink in many places up to his arm pits, if not deeper. Its western end is about one-third of a mile east of the former bed of Mud Lake, and its south side one-half mile north of Heaton Lake, into which its outlet formerly flowed. Between Mud and Cooley lakes there is a ridge of higher ground, part of which is covered with a dense growth of tamarack, swamp huckleberry, button bush and other marsh-loving trees and shrubs.

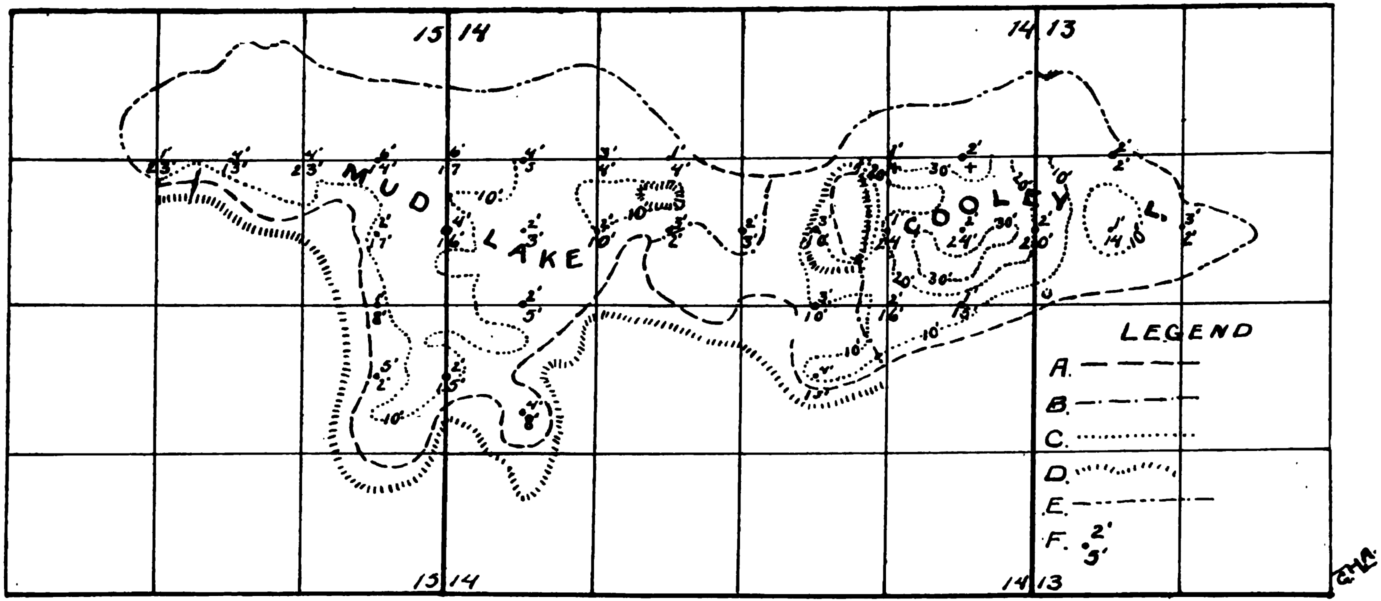


Fig. 40. Map Showing the Deposit at Mud and Cooley Lakes, Elkhart County, Ind.

LEGEND.

A. Approximate limits of marl.
B. Lines separating different qualities of marl.
C. 10-foot contours showing depth of marl.
D. Edge of flat land.
E. Approximate limits of marl in N. ¼ of sections.
F. Upper figure, depth of muck; lower, depth of marl.
A–D–F. From actual surveys made for the Goshen Portland Cement Co.
E. Based on county atlas.

MARL BENEATH MUD AND COOLEY LAKES.—The Goshen Portland Cement Co. has purchased most of the former area of Mud and Cooley lakes, and had an accurate survey made, and many test bores put down to show the thickness and distribution of the underlying marl. These tests were made 20 rods apart by digging a square hole through the muck to the surface of the marl and then taking the depth of the latter. The accompanying map shows in detail the results of these tests.

In July, 1900, Mr. Blatchley spent two days on the property and verified most of the tests made by the representative of the company. With the assistance of Mr. Josiah Replogle 72 bores were put down, mostly at intervals of 20 rods and near or in the holes made by the company. Of these 46 were on the former bed of Mud Lake and 26 around the margins of Cooley Lake. Of those on Mud Lake 14 showed a thickness of marl above 15 feet; 10 showed a thickness ranging from seven to 15 feet; 16 found marl between one and seven feet, while six found only muck.

Of the 26 bores around Cooley Lake, 14 found marl over 16 feet thick; in six the marl ranged from five to 15 feet, while in four it ran from one to five feet. But two bores showed no marl. Over a large portion of the northern half of Cooley Lake, the muck is too thick to justify the working of the underlying marl, if any be present.

All of the marl beneath Mud Lake is overlain by muck, the average thickness of which is about two feet, none of the bores showing over three feet. In Cooley Lake the average thickness of the muck over the marl is one and one-half feet. Wherever the muck ran over four feet, no marl was found beneath.

The marl in Mud Lake is whitish or light yellow in color, while that beneath Cooley Lake is bluish-gray when first uncovered. This difference in color is doubtless largely due to the dryer and more compact form of that beneath Mud Lake.

According to the careful estimate of the Osborn Engineering Co., who made the survey and tests for the present owners, there is 55,-115,400 cubic feet of the yellow marl beneath the former bed of Mud Lake; 16,380,500 cubic feet of grayish marl in the marshy interval between Mud and Cooley lakes, and 67,238,500 cubic feet of "blue marl" beneath Cooley Lake. This shows a total of 5,150,000 cubic yards. As each cubic yard will furnish carbonate of lime sufficient for two barrels of Portland cement, there is marl enough on the property owned by the Goshen company to supply a cement factory having an output of 1,000 barrels per day for 30 years or a 500-barrel-a-day factory for 60 years. This estimate does not take into

consideration the marl underlying Simonton Lake, which can be made easily available by tramway from the site on which the company proposes to erect its factory.

An analysis of an average sample of the light yellow marl from Mud Lake, made by the Osborn Engineering Co., of Cleveland, O., and submitted to the Goshen Portland Cement Co., showed its composition to be as follows:

Calcium carbonate ($CaCo_3$)	82.89
Magnesium carbonate ($MgCo_3$)	2.04
Ferric oxide (Fe_2O_3) and alumina (Al_2O_3)	.64
Insoluble inorganic matter (silica, etc.)	7.94
Organic matter	3.67
Total	97.18

An analysis of the blue marl beneath Cooley Lake made by the same parties resulted as follows:

Calcium carbonate ($CaCo_3$)	88.21
Magnesium carbonate ($MgCo_3$)	4.78
Ferric oxide (Fe_2O_3) and alumina (Al_2O_3)	.88
Insoluble inorganic matter (silica, etc.)	1.42
Organic matter	2.58
Total	97.87

These analyses show a good quality of marl for cement making purposes. The yellow-white marl is lower in magnesium carbonate, and is probably better adapted for cement than the other.

HEATON LAKE.

Not a Workable Deposit.

This lake occupies parts of sections 23 and 24 (38 north, 5 east), Osolo Township. It lies one-half mile southeast of the old bed of Cooley Lake and formerly received the overflow from that body of water. Heaton Lake was ditched about 1885 and its level lowered about five feet. Its outlet, in part artificial, empties into the St. Joseph River. The extreme length of its water area is now about three-quarters of a mile and its greatest width 80 rods. The shallow water along the shores is narrow, except on the west and northwest, where great masses of *Chara* nearly reach the surface and make the passage of a row boat very difficult. The maximum depth is 41 feet, though the greater portion is between 15 and 25 feet. The shores are everywhere low and in most places marshy for five rods back,

when they rise gently; on the north and east into wooded slopes, on the south into cultivated fields or meadows. A vast marsh of cat-tails borders the west shore and continues along the outlet for some distance.

Among the fishermen of Elkhart, Heaton Lake is noted for its bass, which reach a weight of eight pounds; its pickerel, which are often caught up to 15 pounds, and its buffalo or red horse of equal or greater weight.

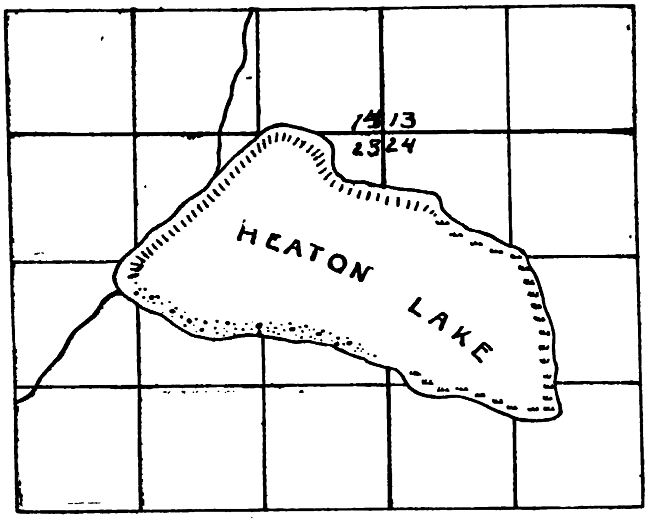


Fig. 1. Map of Heaton Lake, Elkhart County, Ind.

MARL.—But little marl occurs beneath the shallow water of the lake. The bottom of the entire eastern third is of muck beyond the reach of 18-foot auger in one to seven feet of water. Along the middle of the north shore beneath five to seven-foot water the marl is three to six feet thick. On the west shore, beneath the *Chara* above mentioned, the marl is but two feet in thickness with sand beneath. Along the western half of the south shore, the bottom is of gravel in most places, though two bores showed seven feet of a dark colored marl. It is probable that the deeper water is in part underlain with a thicker marl deposit, but there is not enough to attract capital for its development.

INDIANA AND LONG LAKES DEPOSIT.

WORKABLE.

This deposit occupies a semicircular chain of small lakes lying mainly in Michigan, but with their south ends extending into Indiana. Those portions of the deposit in Indiana are on the north

edge of Elkhart County, a little west of north of Bristol. Only the parts in Indiana, or just over the line in Michigan were visited. This includes the deposit in Indiana Lake and in the flat stretch south of Long Lake. Baldwin, Coverdon and Long Lakes in Michigan were not examined.

INDIANA LAKE.

Indiana Lake lies in sections 8 and 9 (38 north, 6 east). Its area is estimated at 100 acres. Except over a small area on the east side of the lake, marl covers the bottom wherever tested. Along the west side the belt of shallow water is very narrow and everywhere showed marl to below reach of the drill. There is more shallow water at the south end of the lake, and a long tongue of similar water juts out from the east shore near the north end, where the marl is deep except close to the shore. In the northeast corner there are a few inches of sand over the marl which here runs from three feet deep on up.

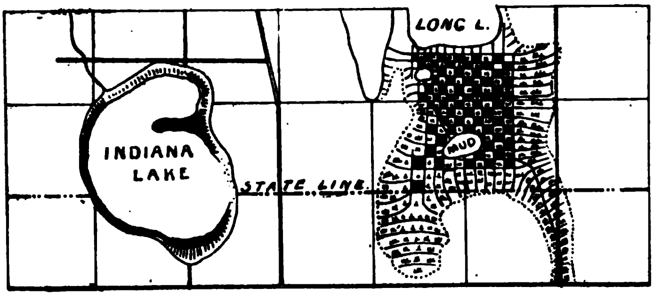


Fig. 42. Indiana Lake and Marl Deposit South of Long Lake.

A half mile east of Indiana Lake is a flat valley extending south from Long Lake. At the south end of this valley the marl is shallow, being but one or two feet deep. Toward the little basin known as Mud Lake it thickens up to over 24 feet, and apparently this or a greater depth is maintained northward to Long Lake. Over most of this area, the marl is overlain by muck, running from 0 to four feet in thickness. As a rule the muck is thin or wanting near the center of the valley and increases in thickness toward the edges. Its average thickness is not far from two and a half feet. There is about 130 acres of marl land in this valley south of Long Lake. The marl in this deposit appeared to be of excellent quality, that in Indiana Lake, especially, being very white. It was formerly burned for lime.

Including the deposits in and around Long, Baldwin and Coverdon lakes, there are reported to be 400 or more acres of marl land which

will run over 15 feet in average thickness. The deposit is, therefore, one of the largest treated in this report, and on account of a large portion of it lying above or in shallow water, it can be readily and cheaply worked. The Monolith Portland Cement Company, with headquarters at Bristol, has already secured a major portion of this deposit and will soon erect near Bristol a large cement plant. A dam is being constructed across the St. Joseph River, which will utilize the 14-foot head of water and so obtain very cheap power, while the Lake Shore and Michigan Southern Railway, passing through Bristol, will furnish an excellent outlet for the manufactured product.

KOSCIUSKO COUNTY.

References.—

1859. Richard Owen, Geol. Reconn. of Ind., p. 208.

1875. G. M. Levette, Seventh Ann. Rep. Geol. Surv. of Ind., p. 483.

1899. Frank Leverett, Water Supply and Irrigation Papers, U. S. Geol. Surv. No. 21, p. 35.

Kosciusko, one of the largest counties in Indiana, lies near the center of the second tier of counties south of the Michigan line. It is bounded on the north by Elkhart, on the east by Noble and Whitley, on the south by Wabash and Fulton, and on the west by Marshall and Fulton counties. Its total area is 521 square miles.

Three railways run entirely across the county, the Michigan Division of the Big Four north and south through its center; the Pittsburgh, Ft. Wayne and Chicago, and the New York, Chicago and St. Louis (Nickel Plate) east and west, the former through the center, the latter across the middle of the south half. In addition to these the Baltimore and Ohio cuts across the northeastern corner, while the Eel River Division of the Wabash just touches the southeastern corner.

The continental divide, separating the Mississippi and Great Lakes drainage systems, passes through the northern third of the county in a northeast-southwest direction. The streams and lakes in the northern tier of townships are, therefore, drained through tributaries of the St. Joseph River into Lake Michigan, while those of the remainder of the county are tributary to the Tippecanoe River, one of the main branches of the Wabash. The Tippecanoe enters the county from the east, a little north of the center and flows across in a westerly-southwesterly course. The streams of the extreme southern part drain into Eel River, also a tributary of the Wabash.

ceedings of the Indiana Academy of Science for 1895. The data relative to the marl deposit was secured by Dr. Ashley in the fall of 1899.

channel flows across the mouth of Johnson's Bay, meeting a short arm deeper than 30 feet from that bay, and comes within 600 feet of the southeast extremity of Ogden Point. This channel continues less than 400 feet wide to a point two-thirds of a mile west of Ogden Point, where it joins the channel deeper than 30 feet from Jarrett's Bay. The deepest water in Jarrett's Bay is 68 feet seven inches, and the area deeper than 30 feet is one-fourth of a mile wide, extending north beyond the mouth of the bay and to within 700 feet of its southern shore. This 30-foot depth joins the main body of the lake a half mile north of Clark's Point, where the channel, 30 feet deep, is only 100 feet wide. Turning to the west, 1,000 feet northeast of the Vawter Park Hotel, this channel deepens to 66 feet five inches, and widens to half a mile directly north of the hotel. Here it meets the narrow channel 30 feet deep from Crow's Bay. The two channels merge into one and form an area of water from 30 to 66 feet in depth, one mile in length and with a maximum width of three-quarters of a mile. This area of deep water lies nearer the south shore, its center being one-third the distance from the south shore to the north shore. Near Black Stump Point the deep water narrows abruptly from the north, and 500 feet out from Black Stump Point its width is but 200 feet. West of Black Stump Point the deep water widens abruptly to the north to a width of a quarter of a mile, and deepens to 63 feet three inches. West of this the area of deep water narrows again and the water having a depth of 30 feet ends one-quarter of a mile southeast of the entrance to the channel between the main lake and Syracuse Lake.

"Between the deep channels from Crow's Bay and Jarrett's Bay the area having a depth less than 30 feet is one and a quarter miles long, 1,300 feet wide, and contains an area one mile long and 500 feet wide over which the water is less than 10 feet deep.

"If the level of the lake were lowered 30 feet there would remain four bodies of water connected by channels from 100 to 200 feet wide and less than 10 feet deep. These four bodies of water would be: (1) A small area in Crow's Bay with a maximum depth of 19 feet; (2) about one-half of Jarrett's Bay with a maximum depth of 38 feet; (3) the main body of the lake, its width decreased almost one-half and its maximum depth being 36 feet; (4) a small area northwest of Black Stump Point with a maximum depth of 33 feet. Lower the level of the lake 10 feet more, that is, 40 feet below its present level, and these four bodies of water would remain as separate lakes, the connecting channels now being dry.

"Great changes in the shore line will take place if the level of the lake be lowered to a much less extent. By observing the map it will be seen that a lowering of the level of the lake to the amount of 10 feet would move the shore line to the first contour line. This would leave one-half the bottom of Johnson's Bay dry land; it would move the shore line along Crow's and Jarrett's Bays from 400 to 1,000 feet into the lake. Clark's Point would extend 2,000 feet further north, and the distance between Clark's Point and Ogden Point would be reduced from 4,000 feet to 1,800 feet. The south shore line from Clark's to Conkling Bay would be moved northward distances varying from 250 feet at Iron Spring Point to 1,000 feet along the shore west of Black Stump Point. The north shore line from Ogden Point to the channel would be moved southward from 900 feet to 2,000 feet, and at one place—between Jones' Landing and Black Stump Point—4,000 feet, reducing the width of the lake at this place from one mile to 500 feet. The channel between the main lake and Syracuse Lake would be drained, and the greater part of Syracuse Lake would become dry land. Judging from the contour of the land the level of the lake has probably never been more than five feet below what it is at present.

The areas below which there is a certain depth of water have been estimated as follows:

Depth of Water.	*Area in Square Miles.*
1—10 feet	3.27777
10—20 feet	.59027
20—30 feet	.62500
30—40 feet	.45833
40—50 feet	.39583
50—60 feet	.22918
60—70 feet	.0694
Total	5.64576

"TOPOGRAPHY OF THE SHORE.—The shore of 20 miles is about equally divided between dry shores and marshy shores. The dry shores are composed of sand and gravel. Some are less than five feet high, but more often they are abrupt bluffs from 10 to 30 feet high, or hills which ascend rapidly to a height of 40 feet. The shore south of Turkey Creek, the outlet, is marshy, and these marshes extend along both sides of the channel between Syracuse Lake and the main lake. Pickwick Park is located on a gravelly shore less than 10 feet above the level of the lake. Between Pickwick Park and Eppert's is the Gordoniere Marsh extending northwest to the

channel. The shore between Eppert's and Jones' is mainly marsh. From Jones' one-quarter of a mile east the shore is a bluff from 10 feet to 15 feet high. From this point almost to Wawasee the land near the shore is at present a dry marsh. The bluff at Wawasee is 15 feet high and extends along the shore 1,700 feet. This bluff extends back from shore 500 feet, where it joins the marsh which stretches along the shore to Ogden Island, and also to the east of Johnson's Bay. On the east side of Johnson's Bay are two bluffs, one reaching a height of 23 feet and extending from Cedar Point northwest one-quarter of a mile along the shore and having 500 feet for its greatest width; the other is 1,000 feet further to the northwest and is between 10 feet and 15 feet high, 700 feet long and 150 feet wide. Lying to the northeast of these bluffs and extending between them is an arm of the Johnson Marsh from 50 feet to 800 feet in width, which joins Crow's Bay just east of Cedar Point. From the northeast corner of Crow's Bay the bluffs extend south along the east end of the lake for half a mile. They are from 10 to 27 feet in height.

"The land on both sides of Turkey Creek, the inlet of the lake, is marshy. Lying to the north of the mouth of the creek this marsh is 400 feet wide and extends one-quarter of a mile north along the lake. This marsh is separated from the marsh along the east margin of Morrison's Island by a shallow channel of water. The west side of Morrison's Island is a bluff reaching a height of 21 feet. From Turkey Creek to Buttermilk Point the shore is skirted with marsh from 200 feet to 400 feet wide. Mineral Point is 200 feet from the lake and ascends abruptly from the marsh to a height of 25 feet. A half-mile south of Turkey Creek the lake is entered by Jarrett's Creek, which is the outlet of a chain of small lakes lying southeast of Jarrett's Bay. This stream flows through a marsh 400 feet wide, and all the small lakes are bordered by marsh land. The marsh along the lake ends at Buttermilk Point, and for a quarter of a mile the shore is dry and sandy. The land along this shore is not a perpendicular bluff, but rises rapidly from the lake to the south and reaches a height of 40 feet at a distance of 400 feet from the shore. The west side of Jarrett's Bay is skirted by a marsh from 150 feet to 1,000 feet wide. West of the marsh is a bluff from 10 to 15 feet high, continuous with the land south of the bluffs of Vawter Park. West from Clark's the south shore of the lake is a perpendicular bluff reaching a height of 29 feet in Vawter Park and extending west beyond the point where our survey of the summer ended. This bluff is cut by a ravine 50 feet wide at

the Vawter Park Hotel and by a small stream entering the lake a quarter of a mile west of Vawter Park. The shore extending west to and around Black Stump Point is from five feet to 15 feet above the level of the lake. The high bluff from Clark's Point to Black Stump Point is by far the longest stretch of highland along the shore, being nearly two miles in length. Conkling Bay during the summer months contained an area of water about 300 feet in diameter and 20 feet deep, bordered by wide stretches of marsh containing a few small pools of very shallow water. To the north of Conkling Bay, Conkling Hill ascends rapidly to a height of 40 feet or more.

"Wherever there is a long stretch of shore bordered by marsh, there is no beach formed, but the muddy bottom of the lake merges into the mud of the marsh along the shore line. Along all the dry shores, and along the marshes of small extent lying between bluffs, the beach is composed of gravel and sand. These beaches along the bluffs are formed by erosion and deposit along the base of the bluffs. The sandy and gravelly beaches along marshes are found where the adjoining bottom of the lake is composed of sand and gravel. These beaches have most probably been formed by the action of ice.

"The lake freezes over and by expansion the ice is pushed up along the shore, carrying sand, gravel and stones with it. Numerous ice cracks form during the winter and fill with water. This water freezes and pushes the ice still further up the shore, carrying the beach-forming material still higher. These ice cracks are very numerous and may be as much as three inches wide. The amount of lateral pressure brought to bear on the shores by this means is very great, and beach ridges are begun and added to each year. The action of the ice in forming beaches along marshes is very great, while along bluffs it is small. In the first case no great resistance is met with in expansion, and the material for building the beach will be carried up to the full extent of the expansion of the ice, while along the bluffs the ice crowds against the shore and is itself broken at every expansion.

"INLET.—The only stream flowing into the lake and containing water throughout the year is Upper Turkey Creek, which enters the lake on the east side of Jarrett's Bay. During the summer months it is filled with an abundant growth of water vegetation, and is without any perceptible current. When the water is high the chain of small lakes lying to the southeast is drained into the large lake through Jarrett's Creek, entering Jarrett's Bay a half

mile south of Turkey Creek. A small stream one-fourth of a mile west of Vawter Park, and another from the east side of Johnson's Bay, contribute water to the lake when the water is high, but not during the dry summer months. There are no springs around Syracuse Lake, but springs are found along the margin of the main lake wherever the shore rises 15 feet or more and extends across the country as elevated territory. These springs usually enter the lake near high-water mark. This gives springs along Crow's Bay, Mineral Point, the south and west sides of Jarrett's Bay, and along the south shore from Vawter Park one mile west. No springs are found along the bluffs at Jones', Wawasee, Cedar Point, Morrison's Island, or Conkling Hill, but in each case these highlands are narrow and surrounded by marsh or lowland. For a half-mile along Crow's Bay the bluff is more than 20 feet high. All along the foot of the bluff the water percolates from the gravel, and at places it flows from quite strong springs. At Mineral Point there are a number of strong springs. At Buttermilk Point and along the base of the bluffs west of Jarrett's Bay are also a number of springs. The margin of the lake from Vawter Park one mile west is very springy, but the flow of water is not so strong as along Crow's Bay. The waters from all these springs show traces of iron more or less strongly.

"OUTLET.—The waters of the lake flow into Lower Turkey Creek through which they enter the Elkhart River near Goshen, Indiana; then through the Elkhart and St. Joseph rivers they reach Lake Michigan.

"Near the outlet of the lake the creek, during the summer, was about 20 feet wide and had an average depth of less than six inches. The volume of water discharged through the outlet was computed from measurements taken in the creek and the overflow of the mill race July 18, 1895. The outflow through the creek was 103 cubic feet, or 772½ gallons, per minute; through the mill race, 41 cubic feet, or 307½ gallons, per minute, making a total of 144 cubic feet, or 1,080 gallons, per minute. At the same time the volume of the creek a half-mile below was computed at 137½ cubic feet, or 1,031 gallons, per minute.

"By taking the outflow of the lake at 144 cubic feet per minute, finding the amount discharged in twenty-four hours, and computing the amount the level of the lake, with an area of five and a half square miles, would be lowered by such an outflow with no inflow, we find it to be .016 of an inch. At this rate it would require 62½ days to lower the lake one inch. In one year of 365 days, at

the same rate, the level would be lowered 5.84 inches. The inflow during the summer months is almost entirely due to springs, and probably equals the outflow. The lowering of the level of the lake, during the summer months, seems to be due almost entirely to evaporation.

"CHANGES IN LEVEL.—The surface of Turkey Lake is 864 feet above tide, and 282 feet above the surface of Lake Michigan. Changes in the level of the lake have been due to three causes: Erosion, the dam which is built across Turkey Creek just below the outlet of the lake, and climatic conditions. Old beach formations give evidence that the level of the lake was formerly five or six feet higher than at present. By erosion the channel at the outlet was cut 10 feet below this ancient level, and the dam has raised the level of the lake five feet to its present level.

"The history of the dam as given by an old settler is as follows: A small dam was built in 1828, to which additions were made in 1831. This dam was washed out in 1833 and the present dam and mill race were begun in the same year. This raised the level of the lake so that timber stood in water five feet deep. Much of this timber remained uncut in 1840, and some was still standing as late as 1865.

"The fluctuations in the level of the lake are caused by climatic conditions, and vary with the inflow and outflow, rainfall and evaporation. The annual fluctuations are estimated to be about two and a half feet. The level of the lake is usually highest about May first, after the heavy spring rains, and lowest in August. The hydrographic basin is so small that at present but seven inches of water are removed from the surface by outflow, while 30 are removed by evaporation. The lake having a surface of 5.6 square miles, an increase of this surface by 7/30, or about one and one-third square miles, would be sufficient to allow all the water coming into the lake to be lost by evaporation except in wet seasons. The surface of the lake, therefore, can not have been very much higher than at present if the present precipitation and evaporation have been constant since the ice left this region."

Mollusca of Turkey Lake.

The following is a list of the mollusca from Turkey Lake as mentioned by Dr. R. E. Call in his various papers on Indiana mollusca:

UNIVALVES.

1. *Limnophysa palustris* Muller.
2. *Limnophysa caperata* Muller.
3. *Limnophysa humilis* Say.
4. *Physa ancillaria* Say.
5. *Helisoma trivolvis* Say.
6. *Campeloma decisum* Say.
7. *Campeloma rufum* Hald.
8. *Goniobasis pulchella* Anthony.

BIVALVES.

9. *Sphærium solidulum* Prime.
10. *Sphærium rhomboideum* Say.
11. *Pisidium rotundatum* Prime.
12. *Unio gibbosus* Barnes.
13. *Unio luteolus* Lam.
14. *Margaritana deltoidea* Lea.
15. *Anodonta grandis* Say.
16. *Anodonta subcylindracea* Lea.
17. *Anodonta footiana* Lea.

Fishes of Turkey Lake.

The following lists of fishes and turtles known to occur in Turkey Lake are from papers by Dr. C. H. Eigenmann in the Proceedings of the Indiana Academy of Science for 1895:

FISHES KNOWN TO OCCUR IN TURKEY LAKE.

1. *Lepisosteus osseus* L. Common Gar-pike.
2. *Lepisosteus platystomus* Raf. Short-nosed Gar-pike
3. *Amia calva* L. Dog-fish.
4. *Amieurus natalis* LeS. Yellow Cat.
5. *Schilbeodes gyrinus* Mitch. Slender Mud Tom.
6. *Erimyzon sucetta oblongus* Mitch. Sweet Sucker.
7. *Pimephales notatus* Raf. Blunt-nosed Minnow.
8. *Notropis anogenus* Forbes. Small-chinned Minnow.
9. *Notropis bifrenatus* Cope. Two-bridled Minnow.
10. *Notropis heterodon* Cope. Variable-toothed Minnow
11. *Notropis microstomus* Raf. Small-mouthed Minnow.
12. *Notropis megalops* Raf. Common Shiner.
13. *Notemigonus chrysoleucus* Mitch. Golden Shiner.
14. *Fundulus diaphanus menona* Jor. and Cope. Top Minnow.
15. *Lucius vermiculatus* LeS. Little Pickerel.
16. *Labidesthes sicculus* Cope. Brook Silverside.
17. *Pomoxis sparoides* Lacépède. Calico Bass.
18. *Ambloplites rupestris* Raf. Rock Bass; Red Eye.
19. *Chænobryttus gulosus* Cuv. and Val. War-mouth.
20. *Lepomis cyanellus* Raf. Green Sunfish.
21. *Lepomis pallidus* Mitch. Blue Sunfish; Blue Gill.

22. *Lepomis gibbosus* L. Common Sunfish.
23. *Micropterus dolomieu* Lacépède. Small-mouthed Black Bass.
24. *Micropterus salmoides* Lacépède. Large-mouthed Black Bass.
25. *Etheostoma nigrum* Raf. Johnny Darter.
26. *Etheostoma caprodes* Raf. Log Perch.
27. *Etheostoma iowæ* Jor. and Meek. Iowa Darter.
28. *Etheostoma microperca* Jor. and Gil. Least Darter.
29. *Perca flavescens* Mitch. Yellow Perch.

Turtles of Turkey Lake.

"Turtles are at all times and everywhere abundant. They frequent especially the shallower portions of the lake. I present here simply a list with notes on their abundance and breeding habits.

1. Chelydra serpentina Linn. Snapping Turtle.

"This species is abundant in Turkey Lake, and reaches a larger size than any of the others. It is caught for the market. It is much shyer than the other species of turtles and is not frequently seen. It inhabits the shallower muddy parts of the lake, being abundant in the kettle and about Morrison's Island.

2. Trionyx spiniferus LeS. Soft-shelled Turtle.

"The soft-shelled turtle is very abundant. It is the second in size and is caught for the markets. Its round eggs are laid in the sand and gravel near the water's edge during June and July. On June 26 one was seen digging a nest in the gravel banks at Syracuse, and on the 27th we obtained eggs from five nests about Ogden Point and other places about the kettle. Other fresh nests were found July 9. The time of hatching was not determined. The number of eggs found in several nests was as follows: 9; 12; 17; 18; 27; 32.

3. Aromochelys odorata Bosc. Musk Turtle; Stink-pot.

"This species is abundant but not conspicuous. Individuals were oftenest seen the latter part of June and first part of July while laying their eggs. The eggs are laid in the rotten wood in the tops of stumps standing in the margin of the lake. The turtles were frequently found in the tops of these stumps, and some of their eggs wedged as far into the rotten wood as a finger could bore. Rotten logs removed some distance from the water are also favorable places for egg laying, and in a mucky place of small area at the edge of the lake 362 eggs were taken at one time. The number of eggs

laid by one individual varies from four to seven, this number being usually in a cluster. At this rate about 60 turtles must have contributed to the nest of 362.

4. **Chrysemys marginata Agassiz. Lady Turtle.**

"This appears to be the most abundant turtle of the lake. How far its apparent abundance may be due to its habits I am unable to say. It is found floating or quietly paddling along, its head out of the water, but on nearer approach it always turns tail and seeks refuge in the abundant *Chara* fields or in other hiding places. The *Chara* fields are traversed by narrow paths and tunnels made by this turtle. The eggs are laid later in the summer and farther from the water than those of the other species. Many were leaving the water in late August; the eggs were found but once.

5. **Malaclemmys geographica Le S. Map Turtle.**

"Next to *Chrysemys marginata,* the most abundant of the turtles. It goes also by the appropriate name of Housetop.

6. **Emys blandingii Holbrook. Blanding's Tortoise.**

"Found in moderate numbers in the lake and along the banks of Turkey Creek.

7. **Clemmys guttata Schneider Speckled Tortoise.**

"But two specimens were seen."

Marl.—Marl occurs in the open water just south of Buck Island but is replaced by muck under the swampy part of the channel. East of Conkling's Hill a large area of marl sets in, covering most of the southeast 40 of section 8 and the southwest 40 of section 9, though not running in close to shore. This area swings around the end of the deep water in this part of the lake and extends southeast along the shore to Black Stump Point. From the mouth of Conkling's Bay to the same point it extends in rather close to shore, often to within 50 feet, and deepens to over 16 feet in a few yards. Tests with a 24-foot auger in this area failed to find the bottom of the marl.

Between Black Stump Point and Vawter Park the marl sets in on the average about 100 yards from the shore and reaches a depth of over 16 feet in a few yards further, and from there out extends below reach of 16-foot pole into deep water.

The marl is distributed very unevenly over the broad shallow area off from Clark's, nearly half the tests showing hard bottom, while the others entered marl without reaching bottom, the water being from three to nine feet deep. Over the long shallow water bar between this and Ogden Point the marl is also irregularly distributed, though a considerable quantity is found here.

From Clark's to Buttermilk Point the marl is found almost if not quite continuously, though it sets in at variable distances from the shore. In the embayment between Buttermilk and Mineral Points the marl is shallow for some distance off shore but reaches a good depth in the center of the bay. Between Mineral Point and Morrison's Island only muck was found. Marl of good depth was found west of Morrison's Island off shore, but runs out southwest and north of the island, where only hard bottom was found. A small amount of marl was found in Crow's Bay, though none in shallow water or close to shore. Some marl was found just southeast of Cedar Point. Two thin beds of sand were passed through in testing here, the first at four feet and the second at seven feet. West of Cedar Point the bottom is hard out to a depth of from seven to nine feet of water, beyond which marl sets in. At the head of Johnson's Bay there is a good deposit of marl, thinning down to about 12 feet at the water's edge but extending half-way to the solid land before running out entirely. Along the sides of the bay the marl is less regular, often being mucky and in places only pure muck was encountered.

At Ogden Point there is a narrow belt of marl on the edge of deep water. From here to Oakland the broad belt of shallow water shows little or no marl. In places it is found on the edge of deep water or in slight depressions in the general level.

SYRACUSE LAKE.

Workable Deposit, Now Being Utilized by the Syracuse Portland Cement Company.

Syracuse Lake is the name given to the northern end of Turkey or Wawasee Lake, it being separated from the main body of the latter by a marsh and island, though rowboats can readily pass by a narrow channel from one to the other. It lies just east of the town of Syracuse on the B. & O. Railway and has a length of a mile and a quarter and a width of nearly three-quarters of a mile. The water area is at present 429¾ acres. A large factory has just been completed by the Syracuse Portland Cement Company for the utilization of the underlying marl.

The topography of the lake is indicated on the accompanying map.* The eastern and southern margins of the lake are shallow and a shallow water belt juts out from the southeast corner of the lake well to the center, giving from four to six feet of water there. Along the northern and western margins the water runs shallow close to shore but rapidly deepens to from 25 to 36 feet. The banks tend to be high along the north side with many sparsely wooded bluffs. Around the rest of the lake they are of moderate height or low. The southeastern corner tends to be marshy.

MARL.—Through the kindness of Mr. J. P. Dolan, of Syracuse, we are enabled to present the accompanying map of Syracuse Lake showing its marl resources as determined by an extended survey. Tests were made every 300 feet, along lines 300 feet apart.

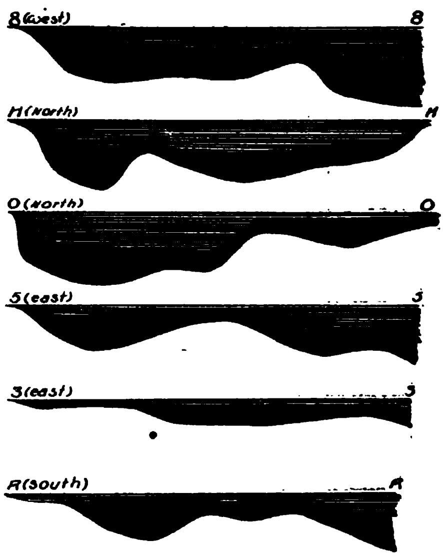


Fig. 44. Cross Sections of Lake and Marl, Syracuse Lake, Kosciusko County, Ind.

These tests show that the marl is inclined to be shallow, or lacking close to shore, a fact readily accounted for by the reason that the present lake surface has been artificially raised several feet. Figure 44 shows, by the width of the solid black bands, the depth of marl over the lake. In a general way this shows an area of deep marl under shallow water in the southeast part of the lake; marl of moderate depth (10 to 20 feet) over most of the rest of the south half of the lake; deep marl (15 to 40 feet or more) over most of the

*See map of Lake Wawasee, Syracuse Lake being included.

north half of the lake, in some cases the marl having depths of 30 to 35 feet within 300 feet from shore. Reference may be made to the accompanying map for the details concerning the deposit.

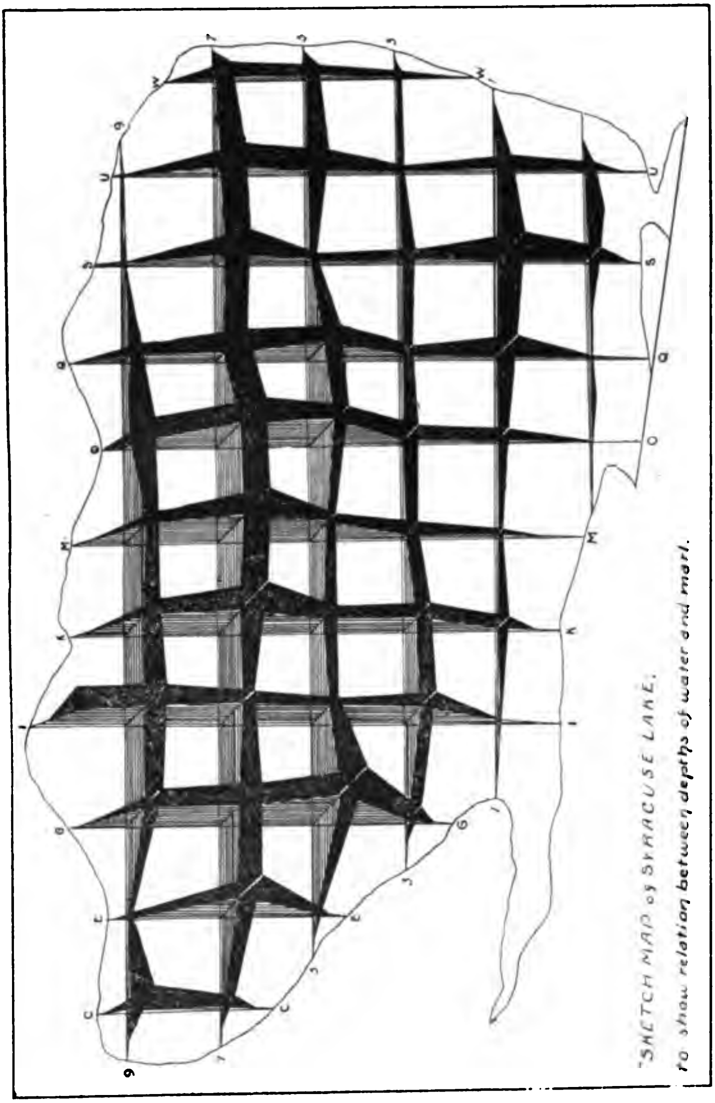


Fig. 45.

Analysis of the marl from Syracuse Lake, made by Prof. S. B. Newberry, of Sandusky, Ohio, resulted as follows:

Calcium carbonate ($CaCo_3$)	88.49	per cent.
Magnesium carbonate ($MgCo_3$)	2.71	per cent.
Iron oxide and alumina	1.21	per cent.
Calcium sulphate ($CaSo_4$)	1.58	per cent.
Insoluble	1.78	per cent.
Organic matter, etc	4.23	per cent.
Total	100.00	

DEWART OR LINGLE LAKE.

Workable Deposit.

This lake lies about four miles southeast of Milford, in sections 25 and 36 (34 north, 6 east), Van Buren Township, and section 30 (34 north, 7 east), Turkey Creek Township. Its northern shore is three and a half miles a little west of south of the Baltimore & Ohio Railway at Syracuse. When visited in the autumn of 1899, it had recently been lowered, very much reducing its area and extent. The water area was estimated to be then over 300 acres, though

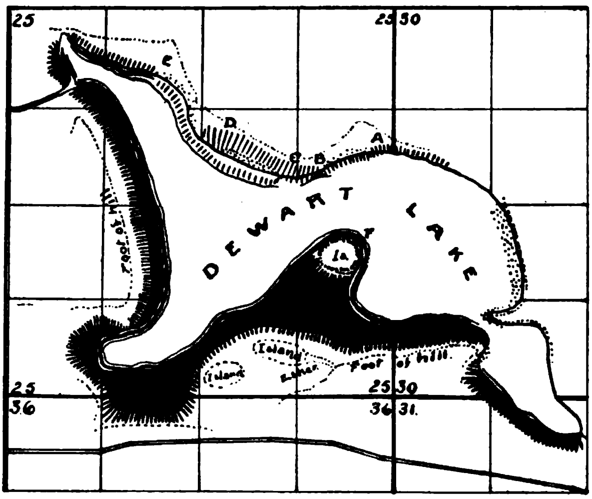


Fig. 46. Map of Dewart Lake, Kosciusko County, Ind.

originally nearly double that. The lake is said to have an average depth of about 30 feet with water running up to 60 feet in depth. A row of soundings, 25 oar strokes apart, on a line starting on the west shore and running east along the center of section 25, gave the following depths of water in feet: 20, 40, 48, 54, 56, 60, 58, 42, 38, 36, 42, 32, 32, 26, 22, 29, 27, 38, 24, 10. The outlet leaves

the northwestern corner and flows northwesterly, passing through Milford or Wabee Lake, finally emptying into Turkey Creek. A wooded island with an area of about two acres rises in the east-central part of the lake. It is now, since the lake was lowered, connected by marsh with the south bank.

Around much of the lake is a belt of flat land flanked by rather abrupt banks. Along the east half of the north shore these banks rise into wooded hills 50 or more feet in height. A flat marshy area eight to 12 rods in width lies between the base of these hills and the water's edge. Toward the northwest this marshy area becomes from 20 to 40 rods wide. At the northwest corner it narrows again to 10 rods or less. Along the north half of the west shore the marsh area runs from five to 15 rods in width with a level area 10 feet higher, back of the marsh. The south half of the same shore has the marsh area narrower with low wooded banks coming close to the water. The marsh area on the south side is much more extensive, running back in places nearly 60 rods from the edge of the water. Above the level of this flat rise two small hills, the one farthest east being connected with the higher main land by a fine example of esker. This marshy flat on the south extends around the southeast corner of the lake and forms the south half of the east shore. The north half of the east shore has high wooded hills with their bases close to the water's edge, gravel banks intervening, the gravel forming the bottom of the lake 100 to 200 feet out from shore in 10 to 15 feet of water.

From the hills to the north the view over the lake is a pretty one, and before its level was lowered, was probably much more attractive. With the exception of rushes, the amount of aquatic vegetation in the present water area is limited. As a fishing resort the lake is noted, and many people, even in a region where lakes are abundant, seek its waters to try their luck in pursuit of the finny tribe.

Marl.—Near the southwest corner there is an unusually large stretch of bare marl of which no bottom could be found with 16-foot drill, until well outside the former shore line and but a short distance from the abrupt bank. An agent of the owners, The Indiana Portland Cement Company, claims that over much of this area it was impossible to reach bottom with a 28-foot auger. Within the old shore line the marl is bare, soft and of good quality. Outside the shore line it tends to be covered with muck reaching a maximum depth, as far as tested, of two and a half feet. It is said that the marl extends around the southeast side of the lake in a similar manner, underlying a large part of the flat belt; also that

it underlies a large marsh south of the two islands and esker mentioned above, being underlain with more or less muck. The shallow water area along the north half of the east shore is underlain with gravel. At the boat house on the north shore, at (A), a short distance west of the north-south township line, the marl is 15 feet thick at the water's edge, and thins out gradually in the narrow marsh between there and the base of the hills, being seven feet thick, 50 feet back. Twenty rods west, and 200 feet out from shore in four-foot water, the marl was but one foot thick with gravel beneath. The low area northwest of the boat house widens in places to 20 rods and most of its surface is formed of gravel. Beneath all water up to five feet in depth opposite this gravel plain the marl runs from one to 10 feet in thickness. At (B), about 60 rods west of the boat house, marl begins to replace the gravel on the marsh north of the lake. At the water's edge the marl is 18+ feet thick, but back 10 rods it has thinned to six feet, and five rods farther back, to two feet.

West of this along shore the marl runs from 0 up to eight feet in two-foot water; while in two bores in five-foot water it was respectively 10 feet and one foot thick. There is not more than 12 to 15 acres of marsh marl north of the west half of the north shore, and over this the marl runs in thickness from two to 14 feet with an average of perhaps 10 feet. Between (C) and (D) a gravel ridge 20 rods wide lies between the main marsh area and the water. Out from (C) beneath five-foot water the marl was 10 feet thick with gravel beneath, while opposite (D) in six-foot water 150 feet out it was but one foot thick. Between (D) and (E) the shallow water area is underlain by marl running from nine feet thick in three-foot water to 14 feet in six-foot water with gravel beneath; the six-foot water line averaging about 150 feet out from shore. At (E), near the extreme northwest corner of the water area, the marl runs 15+ feet thick in three feet of water, 25 feet out from shore. Twenty-five rods southeast of this corner the water is 21 feet deep. Along most of the north half of the west shore the shallow water area is not more than 50 feet wide. The marl beneath water three feet and more deep was everywhere beyond the reach of auger. Over the narrow marsh area bordering this shore the marl runs from six to 15 feet in depth. There are perhaps 10 acres of this marsh. The south half of the west shore was not tested. At (F) on the north side of the island the marl was 17+ feet thick in one foot of water.

There is perhaps 40 acres of shallow water and marsh marl along the north and west sides of the lake. The greater portion of the present water area is over 10 feet in depth. The area of marsh marl on the south side is, however, of sufficient size and thickness to supply a factory for many years. The company owning the deposit propose to work it in connection with that of Milford Lake, connecting the two by an electric tramway, and locating the factory near the Michigan Division of the Big Four Railway just west of Milford Lake.

The quality of the marl in Dewart Lake appears good. That in the south marsh is better than that along the north and west shores. An analysis of a sample from the south marsh, made for the company by Mr. A. W. Burwell, of Cleveland, showed the following percentage composition:

Calcium carbonate ($CaCo_3$)	92.35
*Magnesium carbonate ($MgCo_3$)	3.54
Ferric oxide (Fe_2O_3) and alumina (Al_2O_3)	.53
Insoluble inorganic matter (silica, etc.)	2.00
Organic matter	2.12
Total	100.54

An analysis made by Dr. Noyes of an average sample collected by Mr. Blatchley along the north and east shores resulted as follows:

Calcium carbonate ($CaCo_3$)	84.24
Magnesium carbonate ($MgCo_3$)	2.85
Ferric oxide (Fe_2O_3)	.30
Alumina (Al_2O_3)	.18
Insoluble inorganic matter (silica, etc.)	4.52
Organic matter	5.02
Total	97.11

One is more likely to get foreign organic and inorganic matter mixed with a sample, when the latter is made up of many samples scraped off from the auger, than where the sample is taken carefully from one or two localities in a marsh deposit. An average of the above two analyses will, therefore, perhaps, show more justly the average composition of the entire Dewart Lake deposit. Such an average makes the percentage of carbonate of lime 88.29, which is about what the average Indiana marl will run.

*In the analysis furnished the company the magnesium oxide was given as 1.69. This is equal to 3.54 per cent. of magnesium carbonate, the form in which the magnesia really exists.

MILFORD OR WABEE LAKE.

Workable Deposit.

Milford Lake lies three-fourths of a mile southeast of the town of Milford in sections 16, 21 and 22 (34 north, 6 east). It is a little over a quarter of a mile from the Michigan Division of the Big Four Railway, and about two miles south from the B. & O. Railway. The lake has an area of about 175 acres and an extreme depth of 52 feet. A small and very pretty island occurs in the southeast part of the lake. Around the lake on the south, west and northwest is a considerable area of flat land much of which is well underlain by marl. In places on the north this land rises four to six feet above the present water level. The inlet is from Dewart Lake and enters the eastern end. The outlet leaves the northwest corner and flows northwesterly into Turkey Creek, a tributary of the Elkhart River.

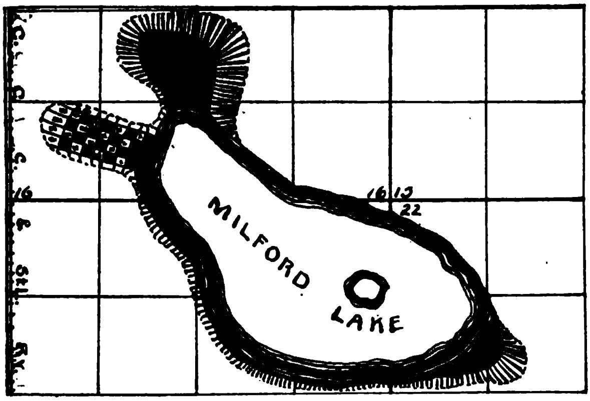


Fig. 47. Map of Milford Lake, Kosciusko County, Ind.

It is said that surveys show that by ditching the outlet it will be possible to largely drain the lake. Soundings along a line running east from the boat house at the west end, and taken at intervals of 25 oar strokes apart showed the following depths in feet: 15, 36, 42, 46, 48, 44. The water is blue and clear, and appears free from sediment or organic matter. Along the north shore, about 50 feet out, the bottom drops down rapidly. East of the island 250 feet, the water is 48 feet deep again. A belt of muck three to five rods wide fringes the shore on the eastern half of the north side. On the east end the rushes extend out 100 to 200 feet from shore. The bottom then shelves into deep water. On the southeast shore the

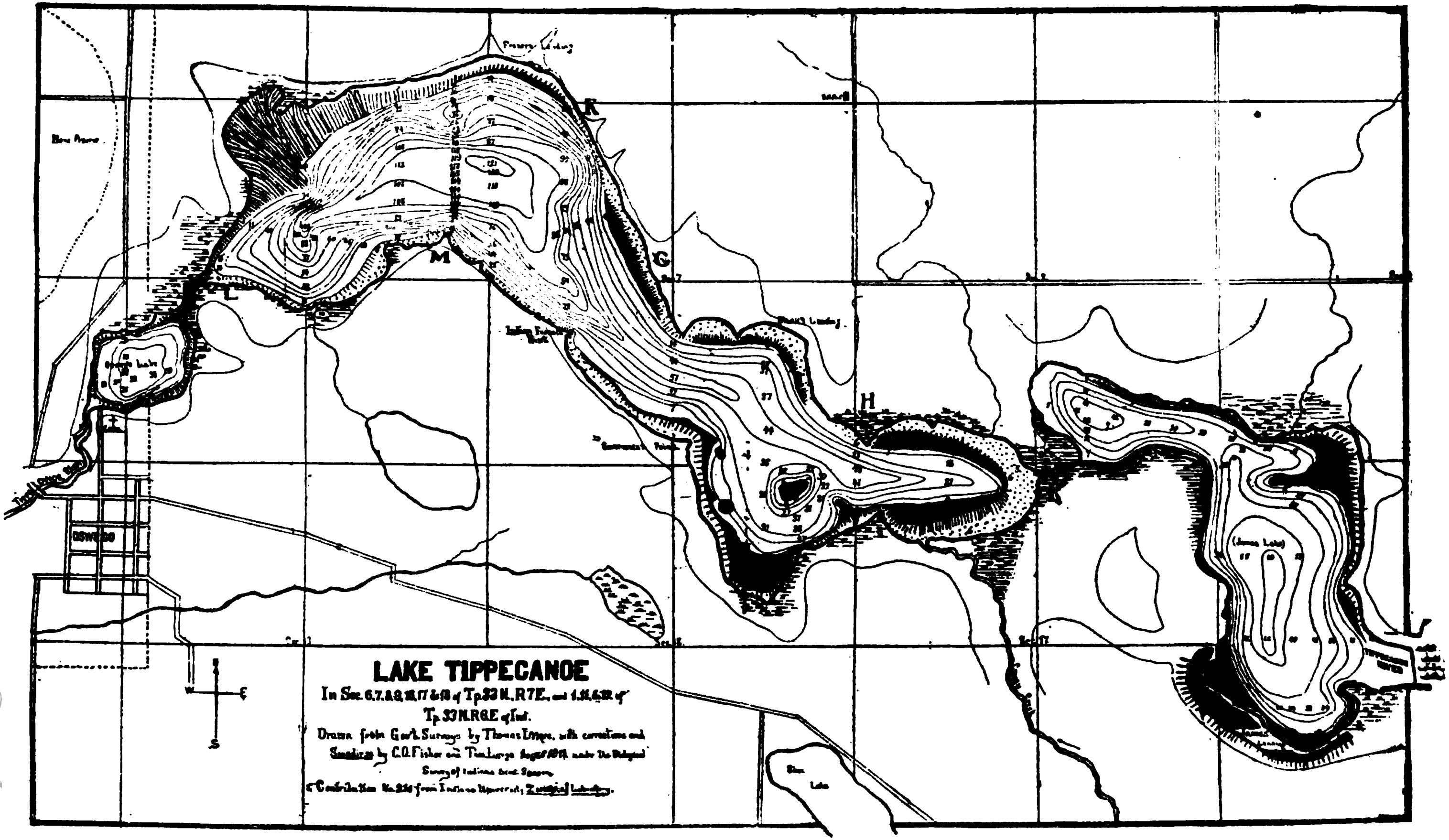


Fig. 48. Map of Tippecanoe Lake, Kosciusko County, Ind.

muck banks rise five feet above the water, and the bottom is of sand 50 to 75 feet out from their base. The remaining portion of the south shore is bordered with a strip of marsh 20 to 40 rods wide and the shallow water area is about 15 rods in width, when the bottom shelves as in other places.

This lake and the surrounding marsh is owned by the Indiana Portland Cement Company of Detroit, which contemplates working the deposit of marl extensively in the near future in connection with that of Dewart Lake.

MARL.—In the mouth of the outlet the marl is 18+ feet thick beneath about eight inches of muck. In the south half of section 16 there is a large area of flat land underlain by marl. The marl runs out at the edge of this flat area but toward the lake thickens rapidly to beyond reach of drill. Except on the east side, all tests made with 18-foot drill around the lake and at the shore nowhere found the bottom of the marl. Beneath the muck banks on the north side of the lake the marl shows two to three feet above the water. On the east side the bottom is of muck for 100 to 200 feet from shore. Over the marl in the marshes outside of the lake there is usually a foot or two of muck, but at one or two places it is said to run up to a maximum of four feet. The marl everywhere appears to be very white with a distinctly granular grain. In places along the water's edge were many of the lime pebbles similar in appearance to those found in Lake James, Steuben County. These pebbles appear to have a concretionary structure, with often a bit of shell at the center.

TIPPECANOE LAKE.

LARGE WORKABLE DEPOSIT.

This is the second largest lake in Kosciusko County, and the fifth largest in Indiana. Its extreme length is about four and a half miles and its greatest width a little more than half a mile. It occupies parts of sections 6, 7, 8, 9, 16, 17 and 18 (33 north, 7 east) and sections 1, 11 and 12 (33 north, 6 east), Tippecanoe and Plain Townships. The general trend of the lake basin is from southeast to northwest, and the total water area is 1.61 square miles. The basin of the lake is divided into three parts. The most eastern, known as James Lake, has an area of about one-half square mile, and is connected with the much larger central basin by a channel about 200 yards long by 150 feet in width. The western basin—Oswego Lake—lies adjacent to the town of the same name, and has an area of only 30 acres.

The lake receives two streams of importance. Tippecanoe River, after flowing through Webster Lake, a mile distant to the east, enters the eastern end of James' Basin and flows through the full length of the lake, leaving it at the western extremity of Oswego Basin. Grassy Creek, the outlet of the Barbee Lakes to the south, enters the middle basin near its extreme southwestern corner. Numerous springs also add to the waters of the lake, either by bubbling up from its bottom or entering near the rim of its basin. The water of the lake is said to vary in level more than four feet at different seasons of the year. The basin of the lake is but a widening of the channel of the Tippecanoe River and this doubtless causes a greater variation in the water level than would otherwise occur. On June 19th, 1900, the water was eight inches higher than on June 8th, while on the night of the 21st an extremely heavy local rain raised it five inches more.

Tippecanoe Lake enjoys the distinction of being the deepest of the Indiana lakes, a maximum depth of 121 feet having been found by Messrs. Large and Fisher near the center of the main basin. The greater part of James Lake is between 30 and 62 feet in depth. The contour lines of the accompanying map show the depths of the various portions of the basin.

This lake is, at present, more nearly in its natural state than any other of the larger lakes of Indiana. But few cottages are found along its shores. No damming or draining have in any way affected it. Its shore line of 12¾ miles is largely bordered by timber land. Especially is this true on the east and north shores, where the wooded bluffs rise in most places between 20 and 40 feet above the water level. Some fine sites for cottages are found on these bluffs, especially on those along the east shore of James Lake and south of Frazer's Landing on the same shore of the main lake. The shallow water area is not wide except on the north shore between Frazer's Landing and the channel opening into Oswego Basin; on the south shore between Government Point and the mouth of Grassy Creek, and around the easternmost bay of the main basin. Especially does the bottom of James Lake shelve off rapidly beneath deep water, the only shallow water areas of any size being opposite the inlet of Tippecanoe River and along the north side of the east shore. In the channels connecting the three basins the water runs from two to four feet in depth. The amount of marsh land around the lake is very limited in area and muck beds of large size occur only in the vicinity of the mouths of the two inlets and in Oswego Lake.

The waters of the two upper basins are remarkably free from aquatic vegetation, while those of Oswego Lake are full of it. In James Lake the muddy area opposite the entrance of the Tippecanoe River is prolific in pond-weeds *(Potamogeton)*,* bladderwort *(Utricularia)* and water-weed *(Philotria)*, while two or three species of rushes *(Scirpus)* occur in numbers, skirting the outer margin of the shallow water areas in other places. The channel between James and the main basin has only its middle third open, the shallow water along the sides being filled with dense masses of pond-weeds, spatterdock and white pond lilies, the root stalks of which are, in many instances, four or five inches in diameter and washed bare and shining. The Indians formerly used these stalks for food, roasting them in pits lined with boulders, the remains of many such pits being found about the lake, especially on the south shore near "Indian Furnace" Point. In Oswego Lake, waterweed, pondweeds, bladderwort, white water lilies, water-shield, duck-meat and many other aquatic plants flourish abundantly, while along the marshy margin are many muck-loving forms, as cat-tails, spatterdock, arrow-arum, pickerel-weed, etc. The decay of these plants is gradually forming muck and filling up this portion of the lake, so that it will be but a few years until it is a vast morass or muck meadow with the deeper channel of the Tippecanoe River passing through its center. The water area of the two main basins is being encroached upon only opposite the inlets and in a few places—as in the southwest corner of James Lake—along the borders of the marshes.

Mollusca of Tippecanoe Lake.

The molluscan fauna of Tippecanoe Lake is a rich one. This is due largely to the fact that the Tippecanoe River flows through the lake, as many thick-shelled *Unios* not usually found in lakes have been thereby introduced. The following is a list of the shells noted in the lake by the writer or mentioned as being found therein by Dr. Call in his numerous papers on Indiana mollusca. Careful collecting would doubtless bring to light many other species.

*The species of pondweed taken in James Basin of Tippecanoe Lake have been identified since the description was in press, and are as follows: *Potamogeton natans* L.; *P. amplifolius* Tuckerm.; *P. heterophyllus* Schreb.; *P. lucens* L.; *P. foliosus niagarensis* (Tuckerm.); *P. pectinatus* L. and *P. friesii* Ruprecht.

UNIVALVES.

1. *Limnophysa palustris* Muller. Common.
2. *Physa gyrina* Say. Common.
3. *Planorbella campanulata* Say. Common.
4. *Helisoma trivolvis* Say. Common.
5. *Amnicola porata* Say. Frequent.
6. *Valvata tricarinata* Say. Scarce.
7. *Campeloma rufum* Hald. Frequent.
8. *Pleurocera subulare* Lea. Abundant.
9. *Goniobasis pulchella* Anthony. Abundant.

BIVALVES.

10. *Unio gibbosus* Barnes. Frequent.
11. *Unio phaseolus* Hildreth. Scarce.
12. *Unio iris* Lea. Common.
13. *Unio subrostratus* Say. Common.
14. *Unio fabalis* Lea. Common.
15. *Unio luteolus* Lam. Abundant.
16. *Unio multiradiatus* Lea. Scarce.
17. *Unio trigonus* Lea. Common.
18. *Anodonta edentula* Say. Frequent.
19. *Anodonta grandis* Say. Common.
20. *Anodonta footiana* Lea. Frequent.

FISHES OF TIPPECANOE LAKE.

The following 27 species of fishes were taken in Tippecanoe Lake by the students of the Indiana Biological Station at Wawasee Lake in the summer of 1895:*

1. *Polydon spathula* Walbaum.† Spoon-bill Cat.
2. *Lepisosteus osseus* L. Common Gar-pike.
3. *Amia calva* L Mud-fish; Dog-fish.
4. *Ameiurus natalis* Le S. Yellow Cat.
5. *Amieurus nebulosus* Le S. Common Bullhead.
6. *Ictiobus cyprinella* Cuv. and Val.‡ Common Buffalo Fish.

*This list is extracted from a general list of the fishes of the region by Dr. C. H. Eigenmann, in the Proceedings of the Indiana Academy of Science, 1895, p. 253.

†According to Capt. B. F. James, a specimen of this fish weighing 153 pounds has been taken in the lake.

‡This species is not given in Dr. Eigenmann's list, but Capt. James assures me that specimens of a buffalo fish, some of which weighed 90 pounds, have several times been taken.

7. *Erimyzon sucetta oblongus* Mitch. Sweet Sucker; Chub Sucker.
8. *Pimephales notatus* Raf. Blunt-nosed Minnow.
9. *Notropis heterodon* Cope. Variable-toothed Minnow.
10. *Notropis hudsonius* Clinton. Spawn-eater.
11. *Notropis megalops* Raf. Common Shiner.
12. *Notemigonus chrysoleucus* Mitch. Golden Shiner.
13. *Coregonus artedi sisco* Jor. Cisco.
14. *Zygonectes dispar* Agassiz Top Minnow.
15. *Lucius vermiculatus* Le S. Little Pickerel.
16. *Labidesthes sicculus* Cope. Brook Silverside.
17. *Ambloplites rupestris* Raf. Rock Bass; Red Eye.
18. *Chænobryttus gulosus* Cuv. and Val. War-mouth.
19. *Lepomis pallidus* Mitch. Blue Gill.
20. *Lepomis gibbosus* L. Common Sunfish.
21. *Micropterus dolomieu* Lacépède. Small-mouthed Black Bass.
22. *Micropterus salmoides* Lacépède. Large mouthed Black Bass.
23. *Etheostoma nigrum* Raf.. Johnny Darter.
24. *Etheostoma caprodes*. Raf. Log Perch.
25. *Etheostoma aspro* Cope. and Jor. Black-sided Darter.
26. *Etheostoma iowæ* Jor. and Meek. Iowa Darter.
27. *Perca flavescens* Mitch. Yellow Perch.
28. *Roccus chrysops* Raf. White Bass.

The following species of turtles were observed while investigating the marl deposits. Three or four additional species undoubtedly occur:

Aspidonectes spinifer (Le S.). Common Soft-shelled Turtle.
Chelydra serpentina (L.). Common Snapping Turtle.
Aromochelys odoratus (Latreille). Musk Turtle; Stink-pot.
Malaclemmys geographicus (Le S.). Map Turtle.
Chrysemys marginata (Agassiz). Lady Turtle.

Several specimen of the lady turtle were found June 20th in a high, sandy cultivated field, 250 yards from any water. They were evidently seeking nesting places.

At present Tippecanoe Lake offers exceptional advantages to the fisherman in search of a quiet retreat. On its wooded bluffs he can pitch his tent with no fear of invading the privacy of some cottager. Over its deeper pools he can troll or cast for black bass, with the assurance that he will cause that gamy denizen to rise and strike; or alongside the weed-covered bars in water of medium depth he can, at times, pull in the blue-gill, cat-fish, ringed perch and war mouth as fast as he can bait the hook. If he tires of fishing and wishes ex-

ercise, he can row full nine miles up and down the lake itself, or, by pulling his boat up the weedy waters of Grassy Creek, can enter the Barbee lakes and add another eight miles to the rowing stretch. All in all, no better fishing and boating resort exists in Indiana than is found along this picturesque chain of lakes.

MARL.—The two larger basins of Tippecanoe Lake contain extensive deposits of marl of an excellent quality. Especially is this true of James Lake, which is everywhere, except over a small area in the extreme northwestern corner, underlain with a thick bed. At James' boat house on the south shore the marl is three feet thick in two feet of water, while 150 feet northwest it is 17+ feet thick in four feet of water. At the three-foot water line around the entire south and west sides it runs 15 or more feet thick, while in most places it is that thick at the margin of the marsh forming the shore, in less than one foot of water. The marsh area west of James' Landing comprises about 30 acres. At the edge, beneath one foot of muck, the marl is 20+ feet thick, while 175 feet back it is practically of the same thickness. The marsh east of the landing is of smaller size, and 70 feet back from shore the marl is 12 feet thick beneath three feet of muck and is underlain with gravel.

In the extreme southeast corner of James' Lake, opposite the Tippecanoe Inlet, muck replaces the marl over an area of 10 acres, but elsewhere the marl was 18+ feet beneath the three-foot water line. Along the south third of the east shore gravel or blue clay underlies the marl in the shallower water, the marl in places being 12 feet thick at the five-foot water line and 10 feet thick at the four-foot water line. Opposite the middle third of the east shore is a large area of shallow water marl which is everywhere, except close into shore, over 15 feet thick. In the extreme western end, north of the entrance to the channel leading into the main lake, the bottom is of gravel in all water less than six feet in depth.

In quality the marl of James Lake is above the average of Indiana marls. An analysis of an average sample by Dr. Noyes shows its chemical constituents to be as follows:

Calcium carbonate ($CaCo_3$)	90.67
Magnesium carbonate ($MgCo_3$)	2.42
Alumina (Al_2O_3)	.06
Ferric oxide (Fe_2O_3)	.26
Insoluble inorganic matter (silica, etc.)	2.48
Organic matter	2.87
Total	98.76

The middle of the channel connecting James Lake and the main basin of Tippecanoe Lake is underlain with marl 16+ feet in thickness, but along the sides, beneath the thick growth of spatterdock, muck only occurs. All water four feet deep and more in the large shallow water area immediately below the channel overlies marl 10 or more feet in thickness. Along the east shore, between the inlet and Wild Cat Point at (H), a number of bores found 17+ feet of marl beneath three to four feet of water 200 feet from shore. One hundred yards southeast of the Point, it was 20+ feet deep at the shore in six inches of water, but was rather dark in color. Between Wild Cat Point and Black's Landing the bottom close to shore, in one to three feet of water, is mostly of sand. The marl sets in a little farther out, beneath four-foot water, being two feet thick, while beneath six feet and more of water its bottom was everywhere beyond reach of 18-foot auger. Between Black's and the east-west township line at (G) the area of sand covered bottom is wider, but the marl is usually 10+ feet thick beneath at least half the water under eight feet deep. Just north of the township line, the bottom is of sand or blue sticky mud as far as (K) beneath all water less than six feet in depth, but in water 6+ feet deep, the bottom of the marl deposit was seldom reached. Below (K) marl sets in and varies from four to 11 feet in thickness at the six-foot water line until Frazer's Landing is reached. West of this landing, along the north shore, the marl thickens and is of better quality. At the three-foot water line 50 to 150 feet from shore it runs 10 to 14 feet in thickness with sand beneath, while at the six-foot line, 200 to 425 feet from shore, it was everywhere beyond reach of drill. Dog-Tail Bay, a wide stretch of shallow water at the northwest corner of the lake, is all underlain with a bed of marl 15+ feet thick. The channel opening into Oswego Lake has marl 14 feet thick along the full length of its bottom. In Oswego Lake the marl thins down to about an average of eight feet with muck two to four feet deep over most of it.

Passing back along the south and west shores of the main lake, we found the marl over most of the shallow water area between (L) and (M) to be thin and of poor quality. It runs from two to eight feet thick in four to six feet of water, while close to shore sand bottom only occurs. Between (M) and Indian Furnace Point, the bottom shelves abruptly into deep water and there is little if any available marl.

South of the Furnace Point the shallow water widens again, and the six-foot water line, as far as Government Point, is underlain with a 10+-foot bed of marl, which thins down to one foot or less before the

shore is reached. From Government Point south nearly to the inlet of Grassy Creek is a shallow water area comprising 80 or more acres over which the marl is everywhere 17+ feet thick. Close in shore there is some muck above it, but in most places it is bare and of excellent quality. This is the largest shallow water deposit in the lake. For some distance on either side of Grassy Creek inlet there is a thick delta of muck which reaches out 200 or more feet into the lake. Beneath this muck the marl, however, occurs, and between the inlet and the channel at (P) it runs from six to 17+ feet thick beneath all water over four feet in depth, while in water less than four feet deep the marl deposit is variable, being in some places wholly lacking, in others one to five feet thick. The bed of Grassy Creek itself contains more or less marl, one bore, 300 yards above the mouth, showing 12+ feet in four feet of water.

An analysis of an average sample from the large deposit south of Government Point gave the following percentage composition:

Calcium carbonate ($CaCo_3$)	91.02
Magnesium carbonate ($MgCo_3$)	2.28
Alumina (Al_2O_3)	.—
Ferric oxide (Fe_2O_3)	0.29
Calcium sulphate ($CaSo_4$)	0.05
Insoluble inorganic matter (silica, etc.)	2.92
Organic matter	2.10
Total	98.66

From the tests made there is little doubt but that most of the deep water of the two main basins of Tippecanoe Lake is underlain with a thick bed of marl of a fine quality. The acreage of that now in shallow water is sufficient for the needs of a large cement factory for many years, but, with the exception of the large bed in the southwest part of the main lake, it is strung along a shore line of great length, thus lessening its availability. The distance from a railway is also a drawback for immediate development, the nearest line being the Michigan Division of the Big Four, five miles to the westward. It would be quite difficult to drain the lake so as to increase to much extent its shallow water area, and it is best that it is so, for its natural beauty is too great to be marred by drainage for the sake of a few thousand dollars, which might be obtained from the marl beds on its bottom.

WEBSTER OR BOYDSTON LAKE.

NOT A WORKABLE DEPOSIT.

This lake lies just east of the town of North Webster, in sections 10, 11, 12, 13 and 14 (33 north, 7 east), Tippecanoe Township. It is very irregular in outline and was formerly a group of two or three lakes, having a maximum depth of 35 feet, which occupied the areas enclosed by dotted lines on the accompanying map. In the early settlement of the country these lakes were surrounded by a marsh which

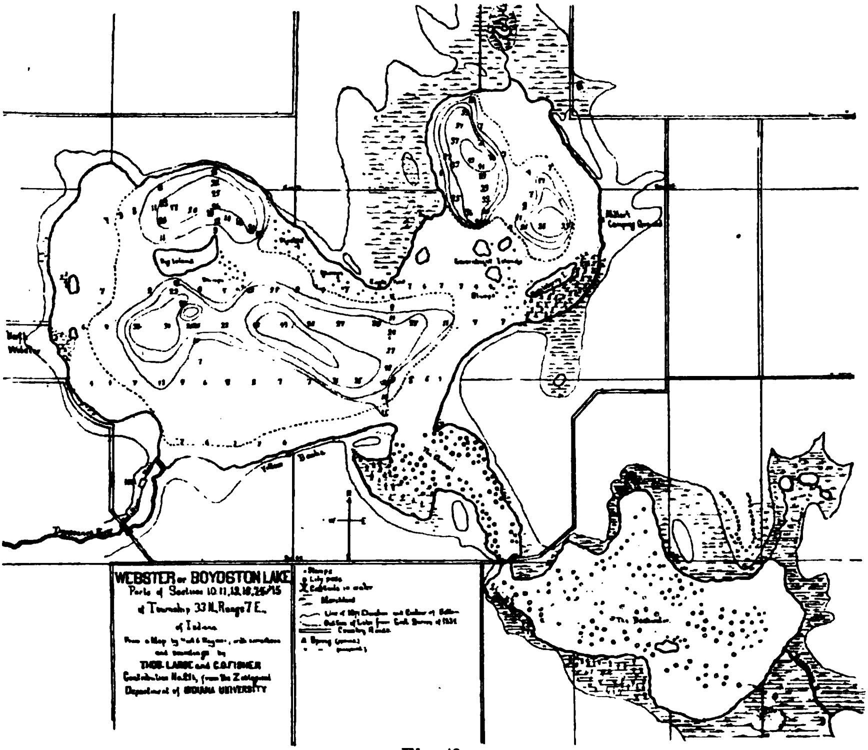


Fig. 49.

reached the margins of the present lake, and there is little doubt but that a natural lake of the same shape and area of the present partially artificial one, once existed here. About 1830 the outlet of the Tippecanoe, which flows through the lake, was dammed to secure water power for a grist mill. This raised the water seven feet, caused it to overflow the marsh of the former lake basin and unite into one body the two or three existing lakes. The "Backwater," shown on the map,

was a low dry tract which by the overflow was covered with water two to three feet in depth.

At present Webster Lake is a very pretty body of water, with an area of 1.057 square miles, and a maximum depth of 43 feet. Seven islands, variable in size, rise above its surface and add to the picturesqueness of its scenery. The shores are varied in character. On the west they are composed of gravel banks 20 or more feet high which slope gently down to the water's edge. On the southwest, about the outlet of the Tippecanoe, they are low and marshy, On the south between the outlet and the channel leading to the "backwater," they rise, from a gravelly beach, 15 feet above the water and are prettily wooded with oak. This stretch is known as "Yellow Banks," and is a popular summer resort. Several cottages are already located and a number of fine sites exist for others.

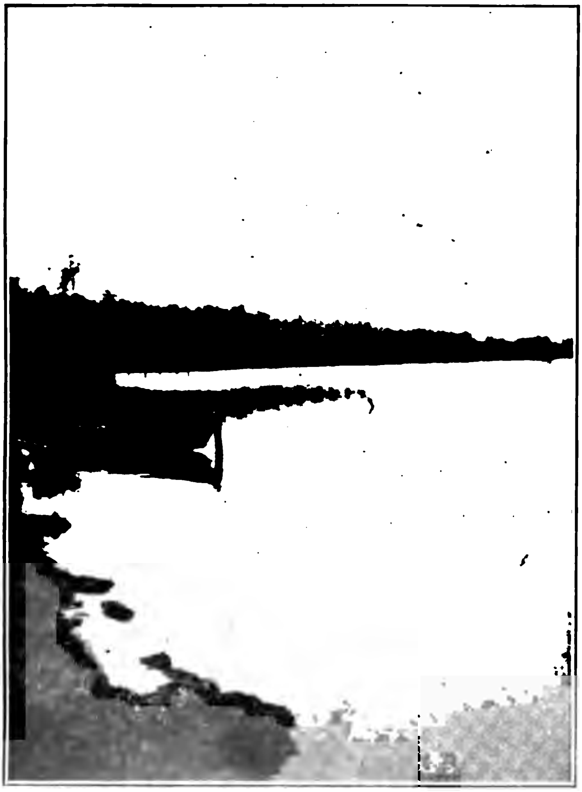
East of the channel the shore is, for a distance, low and wooded, and the water adjacent to it in places contains many stumps and roots of trees which were cut after this portion was overflowed. At "Miller's," on the east side, is another fine cottage site which is partially occupied. On the northeast a strip of marsh land 20 or more rods wide borders the shore. It is in places a quaking bog—10 to 12 feet above the water level. The material composing the higher portions is a mixture of muck and marl thrown up by subterranean springs. The marsh area extends down along the west side of the northeast bay, but the west side of Eagle Point is higher, with gravelly beach and bottom, and many stumps in the shallow water adjoining. Between Big Island and the north shore is quite an area over which the water is from 15 to 25 feet in depth, while southeast of the same island is the deepest portion of the lake.

The more shallow waters of Webster Lake are full of immersed aquatic vegetation, pondweeds, bladderwort, millfoils, etc., being very abundant. The channel leading to the "back-water," as well as the large area of the latter, are literally filled with spatter-dock and white water lilies, while the rapidly forming muck beds about their margins produce rank growths of cat-tail flags, pickerel weed, arrow heads, etc., thus proving the statement previously made, that in a lake which has been raised by damming, aquatic plants flourish more luxuriantly than in one unmodified by man.

The number of species of fish in the lake is not great, but the individuals are numerous and grow to a large size owing to the abundance of plant food. The game fishes, bass, blue-gills, war-mouth and croppies, attract fishermen from long distances and their visits are always

PLATE 11.

a



b

VIEWS OF WEBSTER LAKE, KOSCIUSKO COUNTY.

(a) Stretch of shore at "Yellow Banks."

(b) Showing stumps of trees which formerly grew on part of the present water area.

crowned with success. The following is a list of the fishes known to occur in the lake:*

Amieurus natalis Le S. Yellow Cat.
Erimyzon sucetta oblongus Mitch. Chub Sucker; Sweet Sucker.
Pimephales notatus Raf. Blunt-nosed Minnow.
Notropis heterodon Cope. Variable-toothed Minnow.
Notropis megalops Raf. Common Shiner.
Hybopsis kentuckiensis Raf. Horny-head.
Semotilus atromaculatus Mitch. Horned Dace; Creek Chub.
Notemigonus chrysoleucus Mitch. Golden Shiner.
Zygonectes dispar Agassiz. Top Minnow.
Umbra limi Kirtland. Mud Minnow.
Lucius vermiculatus Le S. Little Pickerel.
Ambloplites rupestris Raf. Rock Bass; Red Eye.
Chænobryttus gulosus Cuv. and Val. War-mouth.
Lepomis cyanellus Raf. Green Sunfish.
Lepomis pallidus Mitch. Blue Gill.
Lepomis gibbosus L. Common Sunfish.
Micropterus dolomieu Lacépède. Small-mouthed Black Bass.
Micropterus salmoides Lacépède. Large-mouthed Black Bass.
Etheostoma nigrum Raf. Johnny Darter.
Etheostoma caprodes Raf. Log Perch.
Etheostoma aspro Cope and Jor. Black-sided Darter.
Etheostoma flabellare Raf. Fan-tailed Darter.
Etheostoma iowæ Jor. and Meek. Iowa Darter.
Etheostoma cæruleum Storer. Rainbow Darter.
Perca flavescens Mitch. Yellow Perch.
Roccus chrysops Raf. White Bass.

MARL.—No marl worth mentioning occurs in shallow water in Webster Lake. Only two of many bores put down in water under 10 feet in depth disclosed marl. One in eight-foot water 250 yards from shore in the southwest part of the lake, found only a trace. The other, off Eagle Point in the same depth of water, found a deposit of dark colored marl six feet in thickness beneath three feet of muck. The deeper portions of the original lakes doubtless possess fair beds, but they are at present wholly unavailable.

* C. H. Eigenmann, Proc. Ind. Acad. Sci., 1895, p. 253.

BARBEE LAKES.

Workable Deposit.

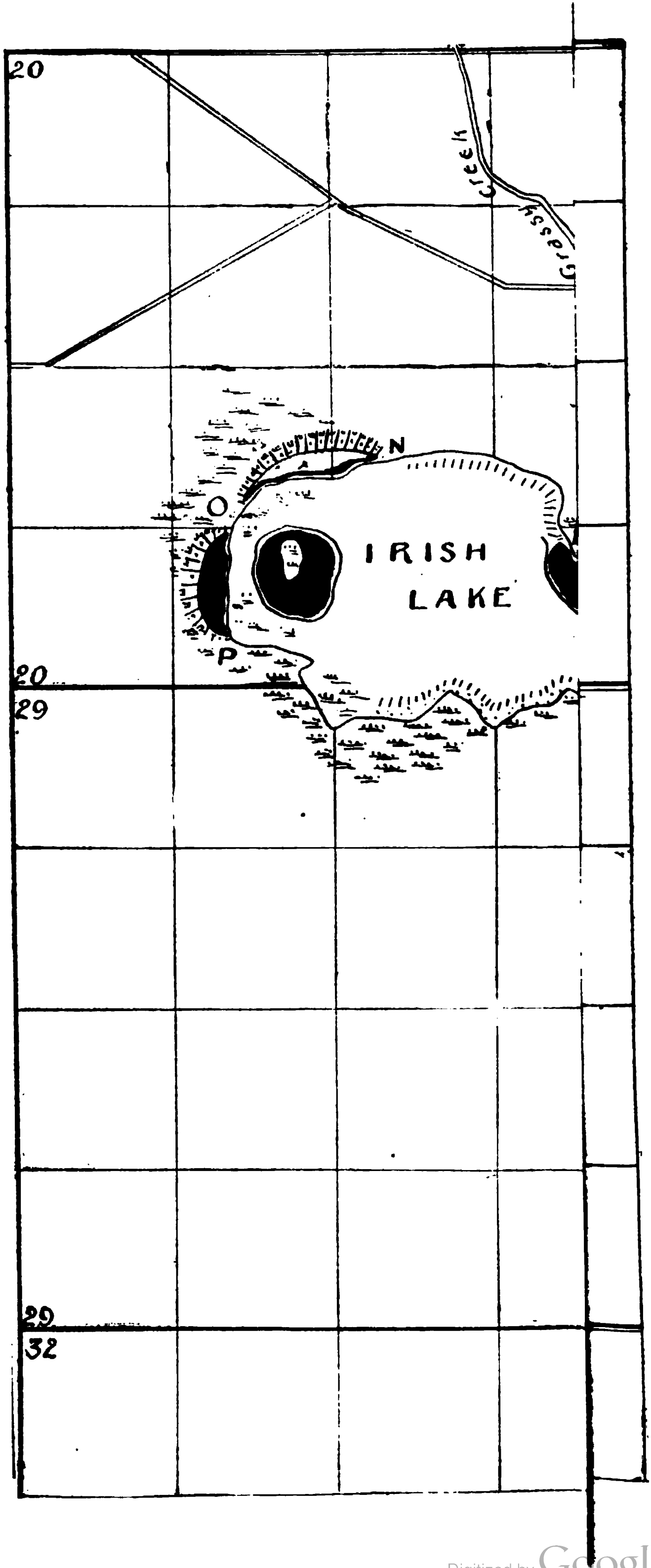
One of the prettiest groups or chains of lakes in Indiana is known collectively by the above name. They are six in number and occupy parts of sections 20, 21, 26, 27, 28 and 29 (33 north, 7 east), Tippecanoe Township. Their inlet, Grassy Creek, flowing northwest from Ridinger Lake, enters the extreme southern end of the largest of the group, Hammon Lake, and leaves, as their outlet, the northern extremity of the smallest, Mabie Lake. The accompanying map of the group, platted from a special survey by Geo. W. McCarter, of Warsaw, shows accurately the relation of the lakes one to another, their relative size, etc.

Where the public road crosses Grassy Creek, at the lower end of Mabie Lake, there was constructed, about 1840, a dam in order to secure power for a saw and grist mill, the latter being at Oswego, three miles northwest. To it an artificial water way or mill race 10 feet wide was constructed. This dam was washed out in February, 1857. During its existence, the waters of the lakes were five feet higher than now and Dan Kuhn and Hammon lakes formed one unbroken sheet of water.

Mabie Lake, the lowest and smallest of the group, is about 1,800 feet long by 750 feet wide and has an area of a little more than 30 acres. Its bottom is mostly of muck and shelves rapidly on all sides into 12 to 15-foot water, the maximum depth being 22 feet. The shores on the north, east and south are low and marshy, while on the west they rise 10 or more feet above the water.

Plew and Kuhn lakes occupy long and narrow parallel basins with a strip of high wooded ground, less than a quarter of a mile wide, intervening. The first named is the larger, being over three-quarters of a mile in extreme length by one-fifth of a mile in width. On the east and north the banks rise 15 or more feet, a narrow strip of marsh lying between their base and the water. The other shores are rather low and marshy. The greatest depth of water is 35 feet, while the area, less than 10 feet in depth, is small.

Irish Lake is the second in size of the group, being a little more than three-quarters of a mile long by one-half mile in greatest width. The greater part of the shore line is low and marshy. The central part of the north shore and the east half of the south shore are wooded and slope gently upward and backward from the water. At the southwest corner there is a large area of muck thickly covered with spatterdock and cat-tails. This extends back to form quite a bay.


20
Grassy Creek
N
O
IRISH
LAKE
P
20
29
29
32

Fifteen rods east of the west shore is an island about two acres in area. It is covered with stumps, rushes and cat-tail flags, and rises three feet above the water level. The shallow water area of Irish Lake is narrow, except along the east half of the north shore, where it extends out 200 yards or more into the lake. The greatest depth of water found was 32 feet. There is much *Chara* on the bottom along the north side, and many aquatic plants flourish luxuriantly in the muck beds about the island near the west shore.

Kuhn Lake, 180 rods long by 70 rods wide, is surrounded by low banks except on the north, where they rise gradually into the narrow ridge separating Kuhn from Plew Lake. Its maximum depth July, 1900, was 34 feet.

Hammon Lake is the largest of the group, its extreme length from northeast to southwest being just about a mile, while its greatest width is a little more than three-fifths of a mile. Its outline is quite irregular, a broad strip of land extending into its basin from the west. At Hammon's Park, on the northeast shore, wooded bluffs rise 40 or more feet a short distance back from the water's edge, otherwise the entire shore line is low and in most places marshy. There are several rather large areas of shallow water in different parts of the lake, but the greater portion of the water runs between 18 and 35 feet, while 42 feet was the maximum depth sounded. About the inlet of Grassy Creek, extensive beds of muck are slowly encroaching upon the water area. On their sub-aqueous portions pond-weeds, bladder-wort and other immersed plants flourish in profusion and, by their decay, add each year to the thickness of the slowly rising bottom. In this portion of the lake are also large numbers of water lilies, both white and yellow.

The ridge separating Dan Kuhn from Hammon Lake is about 200 feet wide and in its highest portion only three or four feet above the water level. It is covered with marsh grasses and sedges except about the old channel where dense thickets of cat-tail flags occur. This natural channel near the north end of the ridge is now choked with vegetation, but a new artificial one has been cut across farther south for the use of row boats. Dan Kuhn Lake is a little more than half a mile long by one-quarter of a mile in average width. It is the most shallow of all the lakes. The average depth is probably less than 12 feet, the maximum found being 19 feet.

The Barbee lakes are renowned as fishing resorts. The species occurring are practically the same as in Tippecanoe Lake. Irish Lake, especially, is noted for the number and size of the large-mouthed black bass which are found therein. Two club houses have been

erected by disciples of Izaak Walton from Anderson, Indiana, and if their tales are to be relied upon, each season's catch is certainly phenomenal.

MARL.—A fine deposit of marl exists in Dan Kuhn and Hammon lakes. A large area along the west side of the former is covered with water from one to three feet deep beneath which no bore with 21-foot auger found the bottom of the bed of marl. Around the north and east shores there is 16+ feet everywhere beneath the four-foot water line, 150 feet out. Along the south shore in five-foot water the bed thins down to eight feet with sand beneath. The quality of the marl is excellent.

On the west and north sides of Hammon Lake between (A) and (B) the bottom of the marl bed could not be reached with an 18-foot drill in all water from the shore out 175 to 250 feet in the lake. From (B) to (C) sand was found next to shore beneath four to eight feet of marl in two to five feet of water, but at greater depths the bottom of the marl bed was beyond reach of drill. In the bay between (C) and (D) the shallow water area is extensive, reaching out 300 or more yards, and overlies marl 15+ feet in depth. Between (D) and the channel at (E) the bottom is of gravel for 75 feet out, when marl sets in, being 8+ feet thick at the eight-foot water line. From the channel nearly to the inlet, at (F), the marl is 14+ feet thick on the four-foot water line 75 to 100 feet from shore. On both sides of the inlet a thick deposit of muck covers the marl. Opposite (G) the marl appears free from muck, being 12+ feet thick at the six-foot water line 125 feet from shore. Out from (H) the bottom shelves down close to shore and in seven-foot water gravel underlies eight feet of marl. Adjoining the north side of the projecting strip of land at (I) is a large area of water only two to five feet deep, which is everywhere underlain with a marl bed 12+ feet in thickness. A similar shoal area is found opposite the channel leading to Kuhn Lake, but here the water is only six to 18 inches in depth while the marl is but six to 10 feet thick. Along shore, between (I) and (K), the marl was three to five feet thick at the water's edge and beyond reach of auger in three-foot water.

In Kuhn Lake shallow water occurs only along the margin, the four-foot line averaging about 75 feet out. The marl along the south shore is 14+ feet thick at this line, but on the north shore it averages only about 10 feet, with sand underlying. The quality is much inferior to that in the two lakes to the eastward, it being darker and, in places, gritty.

Along the north side of Irish Lake between (L) and (M) the shallow water is 200 yards wide and underlain with marl 16+ feet thick. At the shore there is usually one or two feet of muck over the marl. Between (M) and (N) the shore margin is of gravel or sand and the marl is only three feet thick at the six-foot water line, 150 feet out. A marsh of 20 or more acres borders the shore between (N) and (O). For 200 feet back this is composed wholly of a fine grade of marl 18+ feet thick. Then muck sets in, and at 250 feet is three feet thick above 10 feet of marl. Between (O) and (P) a similar marsh of marl extends back 200 to 275 feet, the marl running from 10 to 18+ feet thick, in many places bare, in others overlain with one to three feet of muck. Quite a body of shallow water marl also occurs around the island east of this marsh, but the bottom of the southwest bay is of muck only. Along the south shore gravel forms the bottom for 50 to 75 feet out, the marl averaging only about seven feet along the six-foot water line.

No marl was found in the shallow water of Mabie Lake, but in Plew Lake it occurs along the shore beneath all water three feet deep and over, the bottom of the bed being beyond reach of drill in all tests but one.

The greater portion of the bottom of this group of lakes is thus shown to be formed of a thick marl deposit. That in Dan Kuhn and the shallow portions of Hammon Lake is most available, and both in quantity and quality will well justify the investment of capital for its development. If necessary, the channels between the lakes could be easily enlarged so that the marl in and about Irish and Plew lakes could be transported in barges to a factory located near the larger deposits.

RIDINGER LAKE.

Large Deposit, Mostly Under Deep Water.

This lake occupies parts of sections 1 (32 north, 7 east) and 36 (33 north, 7 east), Washington and Tippecanoe townships. It lies in a long and rather narrow valley which trends almost due north and south. The total length of the water area, according to careful measurements made by County Surveyor McCarter, is 4,600 feet, while its width averages about one-third of a mile, the area being close to 300 acres.

The outline is quite regular, there being but two bays, one of about 10 acres in the southwest corner, the other much larger in the northeast. The inlet which enters on the south side is a stream which

comes from Cedar and Robinson lakes, Whitley County, while the outlet is Grassy Creek, flowing from the northwest corner, north and then west into the larger of the Barbee lakes. A dredge ditch now being dug in Whitley County has been surveyed to the lake, and from it northward, which will lower its waters four or more feet and destroy much of its natural beauty.

At Weaver's Landing, near the middle of the west shore, there is a pretty bit of woodland sloping gradually down to the water's edge. The south half of the east shore slopes up from a gravelly beach into wooded hills, while the north half of the same shore bends rather abruptly to the east to form a wide bay, the shores of which are a willow-covered marsh, 10 rods or more wide. The north and south shores of the main lake are, for the most part, low and marshy, especially about the inlet and outlet. The greatest depth of water found was 45 feet near the center of the north half. The most of the water area is between 20 and 35 feet in depth.

MARL.—At Weaver's Landing the bottom for 50 feet out is of gravel, and shelves rapidly into deep water. Twenty rods south, in six-foot water 100 feet from shore, marl occurs 12+ feet in depth. Over the shallow water area of the southwest bay it runs about the same, except close in shore where it thins down to four feet or less. Along the west half of the south shore it is everywhere 14+ feet in four feet of water. The bottom is here covered with *Chara* and the marl is excellent in quality, the six-foot water line being about 125 feet from shore. One hundred yards west of the inlet the marl is 16+ feet thick in two feet of water. On either side of the mouth of the inlet there are large patches of spatterdock and white water lilies, beneath which muck only occurs to a depth of 14+ feet.

Along the south half of the east shore the bottom is of gravel out to the six-foot water line, where the marl sets in and thickens rapidly. In the south half of the northeast bay there is muck close to shore but 125 feet out marl 10+ feet thick underlies two feet of muck in six feet of water. In the extreme northeast corner of the lake 100 feet from shore, 11+ feet of marl is found at the seven-foot water line. At the point where the east-west township line strikes the lake, the marl is 14+ feet in three feet of water, and runs about the same until near the outlet, where it is partially replaced by muck. Along the north half of the west shore it is everywhere 10+ feet thick beneath six feet of water, while in three-foot water, 175 feet out, it has thinned down to three feet.

The tests show that practically the entire lake bottom is a bed of marl of good thickness and fair quality. That portion in shallow

water is, now, small. The proposed ditch will greatly enlarge it, but will not likely make available an area sufficient to justify its development for cement making.

LITTLE EAGLE LAKE.

Workable Deposit.

This lake occupies parts of sections 24, 25, 26 and 35 (33 north, 6 east), Plain Township. It is about three and a half miles northeast of Warsaw and two and one-half miles east from the Michigan Division of the Big Four Railway.

The banks of the lake are irregular, in places being flat some distance back, in others rising gradually 20 or more feet above the water level. The lake has been twice lowered, the total decrease in level being about six feet, thus rendering prominent broad belts of low land along the south side and the northeast corner of the main basin; most of the old west embayment is also dry. A strip some 225 yards wide between the main lake and the south arm, through which a channel is cut, is also a wet marsh, while large areas of the western side of the south arm are above water. The former water area of the lake was about 850 acres. The present area is at least 150 acres less, the difference being left as marsh except a small portion of gravel beach on the south side.

Marl.—In the south arm of the lake the shallow water belt is narrow along the east side and the marl is shallow except on the edge of deep water. Along the west side the reed covered marsh extends well out into the lake. Drillings on the edge of this showed at every point marl to below 16 feet. The marsh of 30 or more acres lying to the west of this lobe of the lake is covered with muck, the depth of which ranges from four to 20 feet. Beneath the muck on its northern third is marl running from six to 12 feet in thickness, but the southern portion is wholly of muck. There appears to be at least 50 acres underlain with marl in this part of the lake.

Between the south lobe and the main lake there is a marsh (F. J. K.) of 30 or more acres in which marl comes to the surface, over the most of which it ranges from six to 25+ feet in depth. At the south end of the channel, cut through this marsh, there is about a foot of muck above the marl, but elsewhere the marl forms the surface. The former lobe of the lake, west of the point at (K), is now nearly all a marsh, which, in summer, is covered with wire grass, rushes and sedges. At the east side of this marsh the marl is shallow, running

only from two to five feet in depth. This is owing to the proximity of the high point which separates this arm from the main lake. The remainder of this marsh area of 80 or more acres is underlain with a fine quality of marl which runs from nine to 25 feet in thickness.

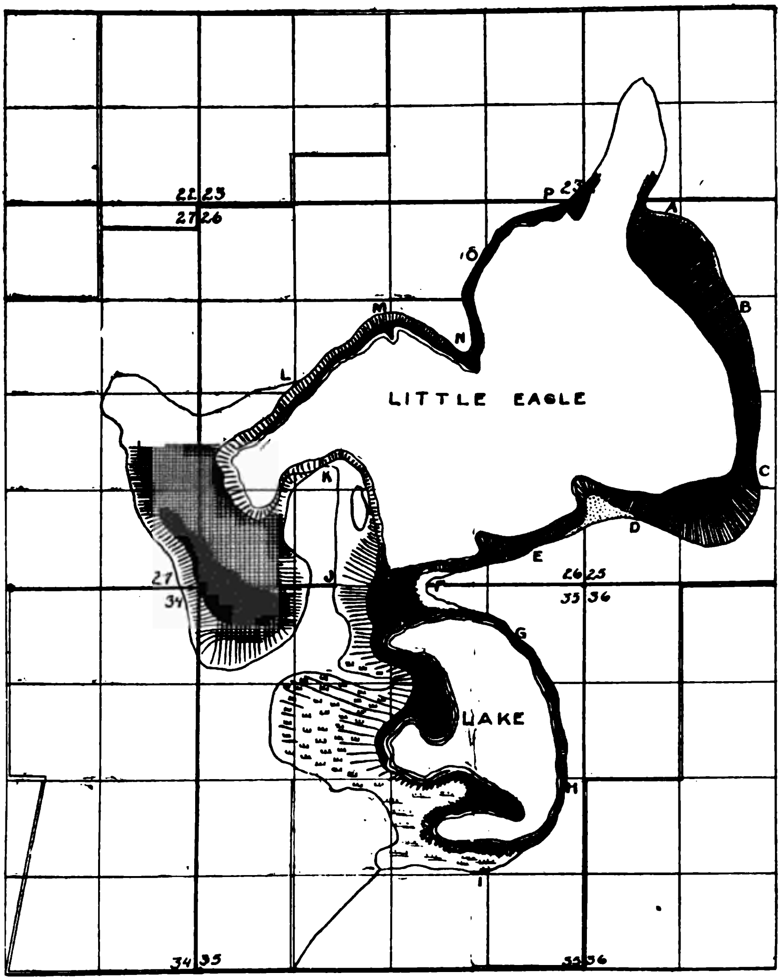


Fig. 51. Map of Little Eagle Lake, Kosciusko County, Ind.

Along the south side of the main lake the shallow water forms a broad belt from 200 to 1,000 feet wide, deepening very gradually. Near the center a broad point of hard bottom covered with very shallow water extends well out into the lake, otherwise the shallow water is underlain by marl. This tends to deepen gradually from the shore outward, so that the average depth under the shallow water is

probably not over 10 or 12 feet. For a space along the east shore the bottom is hard for some distance out, but in six or seven feet of water showed marl to below reach of pole. The northern half of the east shore shows a broad belt of shallow water marl, the width being in places between 500 and 1,000 feet. The depth seemed irregular but is similar to that along the south side. Along the north bank the belt of shallow water marl is narrow, ranging at most places between 50 and 150 feet wide. The marl, however, seems to run much deeper than at corresponding distances from the south shore. There is little doubt but that three-fourths or even more of the deep water area of the lake is underlain with a thick deposit. The shallow water and marsh areas are, however, sufficient in acreage and thickness to furnish material for a large cement factory for many years.

The quality of the marl in Little Eagle Lake runs from poor to good. In the south lobe of the lake much of the deposit appeared mucky, especially at the south end. That in the main lake appeared of much higher quality, being a light brown to gray. An analysis by Dr. Noyes of a sample, taken from about two feet below the surface by Geo. W. McCarter, the owner of a large part of the marsh area about the lake, gave the following percentage composition:

Calcium carbonate ($CaCo_3$)	84.75
Magnesium carbonate ($MgCo_3$)	2.84
Ferric oxide (Fe_2O_3)	0.35
Alumina (Al_2O_3)	0.15
Calcium sulphate ($CaSo_4$)	0.07
Insoluble inorganic matter (silica, etc.)	4.61
Organic matter	5.69
Total	98.46

An average sample from a greater depth will, without doubt, show a higher percentage of carbonate of lime, and a lower of organic matter.

CENTER AND PIKE LAKES.

Workable Deposit.

CENTER LAKE.

Center Lake lies north of and adjoining the city of Warsaw. It is situated in sections 5 and 8 (32 north, 6 east), Wayne Township, and its eastern shore is but a few rods west from the Michigan Division of the Big Four Railway. The present water area covers about 200 acres. The banks are low on the north and northwest; otherwise the

ground around the lake slopes up gently to a height of 10 to 20 feet The water is 80 feet deep not far from the shore in the southwest part and nearly as deep in places near the east shore. The lake is fed by a small stream from the northeast. The outlet leaves the west side and after a tortuous course of two or three miles flows into the Tippecanoe River. The area of shallow water is, as a rule, narrow, 50 to 150 feet wide, except at the north end, where there are several acres of shallow water, partly grown up with rushes.

MARL.—The most of the marl found was at the north end, where none of the tests reached bottom at 16 feet in one to four feet of water. Along the east side the distribution of the marl is irregular. Near the center of this side the bottom was found to be hard out to beneath 10 feet of water, then marl sets in. A little north of this six feet of marl was found in three feet of water.

In the southeast corner tests in water from three to 15 feet deep gave only one or two feet of marl. Just north of the end of Buffalo street, at the extreme south end of the lake, five and a half feet of marl was found in one and a half feet of water close to shore and at 50 feet out in four feet of water, the marl ran below pole, as it also did 200 feet out in seven feet of water. The southwest part of the lake showed marl just equaling in depth the water up to eight feet as far as we could test. In the northwest part of the lake hard bottom or only a few feet of marl occurs.

PIKE LAKE.

Pike Lake lies one-half mile east of Center Lake, the Michigan Division of the Big Four Railway passing between the two. It occupies parts of sections 4, 5, 8 and 9 (32 north, 6 east), Wayne Township. The north end is within a few rods of the Big Four Railway and its south end is a little over half a mile from the Pittsburg, Ft. Wayne & Chicago Railway. On the west, east and southeast the banks slope up 15 to 25 feet above water level. On the north and extreme south the banks are low. The embayment on the east is shallow, most of its surface being covered with less than 10 feet of water. Just west of the point at the cemetery the deep water comes quite close to the shore. Around the rest of the shore, the water deepens gradually. The total area of the lake is about 250 acres.

MARL.—A small lobe of the lake at the north end is now practically shut off from the main body and was not examined. The main deposit of marl occurs in the eastern embayment, covering probably 20 to 30 acres and extending at every point tested to below

16 feet under the water surface. West of the cemetery no marl was found. At the south end of the lake, nearest Warsaw, the marl runs back under the bank 75 to 100 feet, having at the former distance a depth of five feet with little or no muck overlying. At the water's edge the marl is six feet deep, and nine feet deep in three feet of water. In the southwest corner the marl does not set in close to shore, only one foot of marl occurring in seven feet of water and four feet of marl in 10 feet of water, 75 feet from shore. Along the west bank next to the park no marl was found, until the north end was approached, where three feet of marl is found in eight feet of water, while further out it deepens to below reach of drill.

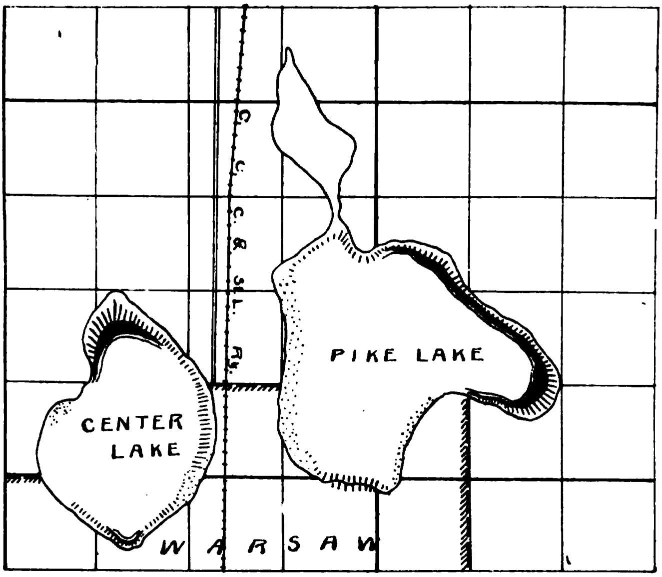


Fig. 52. Map of Center and Pike Lakes, Kosciusko County, Ind.

Along the north side the marl does not set in until the water reaches a depth above three feet. In four-foot water the marl runs from one to three feet, while near the section line the marl is only three feet deep in 10 feet of water. Further east it extends below reach of drill in five feet of water.

The quality of the marl is variable, the best occurring just north of the cemetery. The marl in the north part of the lake is mucky; that at the south end generally good. The deposit beneath Pike Lake is not of itself large enough to be termed workable, but taking it in connection with that beneath Center Lake, a fair workable deposit is presented. Lying as close as it does to excellent railway facilities, it offers a good location for a factory site.

EAGLE OR WINONA LAKE.*

WORKABLE DEPOSIT.

This lake lies one mile southeast of Warsaw and occupies parts of sections 15, 16, 17, 21 and 22 (32 north, 6 east), Wayne Township. It consists of a main body of water, almost a square mile in area, and a small bay on the northwestern side connected by a narrow channel. The catchment basin is large as compared with the size of the lake itself. Unusually heavy rains change the lake level as much as two to two and a half feet. The tributary streams are three in number. The largest is Cherry Creek, which flows into the lake on the southeast. For the most part it flows through woodlands. Two other streams, the larger of which is Clear Creek, enter the lake at its extreme southern part. The output of Clear Creek is nearly as much as that of Cherry Creek. Numerous springs on the Winona Assembly grounds, as well as a number bubbling up from the bottom, also add to the waters of the lake. The outlet is a small stream from the south end of the northwest bay, which finds its way into the Tippecanoe River at a point one mile northwest of Warsaw. The shore line, for the most part, is low. On the north, a small stretch of cultivated land rises rapidly to a 10-foot elevation line. The Winona Assembly grounds on the east have the greatest elevation. This elevation is from 10 to 50 rods back from the lake. The other parts of the grounds lie below a 10-foot line. The south shore is uniformly low and swampy. On the west, an abrupt rise is found at Yarnell's Landing. To the north of the landing the shore is low, and the elevation gradual. Natural woodland is found at Yarnell's, at the outlets of both Clear Creek and Cherry Creek and on the Assembly grounds.

The greatest depth of water in the lake is 81 feet near the center of the main body. The contour lines on the accompanying map show the depth in other portions. It will be seen that the embayment in the northeast corner runs shallow, and a belt of shallow water from 50 to 150 feet or more wide, runs all along the eastern and southern side. Along the north shore the belt of shallow water is broad but irregular.

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*Much of the general data relative to this lake, as well as all of the information concerning the plants and vertebrate animals, was kindly furnished by Prof. Earl E. Ramsey of the Muncie High School. Prof. Ramsey has been connected with the Summer Biological School at Winona for several seasons, and has thus had most excellent opportunities for securing information.

The area covered by water is .987 of a square mile, or 631 acres, and there are probably 125 acres of marsh land adjacent. By reference to the map of Eagle Lake prepared by the U. S. survey in 1834, it will be seen that the lake was then considerably larger than now. The difference in area has been brought about, first by dredging the outlet channel and lowering the level of the lake. Second, the en-

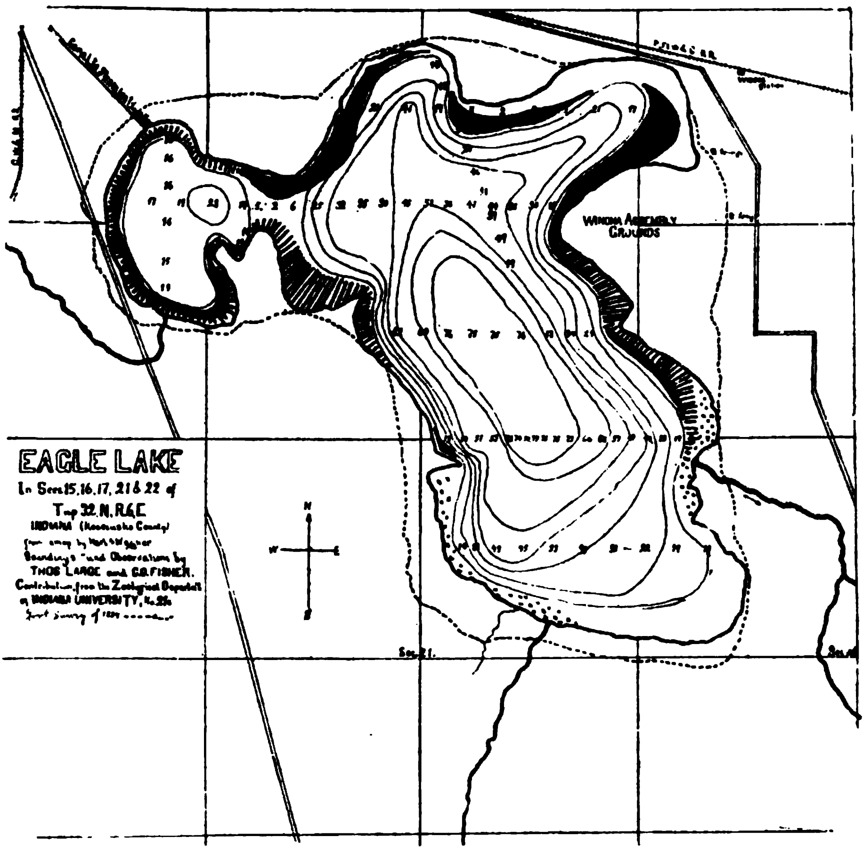

Fig. 53. Map of Eagle Lake, Kosciusko County, Ind.

croachment of plant life upon the lake proper and the luxuriant plant life on the land partially dried by lowering the lake level. As noted farther on, the plant life in the lake is abundant. The dense beds of *Scirpus*, *Nuphar*, etc., tend to collect material that may float into them and also contribute their own growth to the formation of new lake bottom. A third agency which has acted in some parts of the lake—notably the southern part—is that of the ice.

With the lowering of the lake level, stretches of lake bottom were left barely covered by water and were in most cases separated from the land by deeper water. As the ice formed, it pushed the ground higher on these shallow places. The ice cracks in exceedingly cold weather. The cracks fill with water and freeze again and crowd the ice and the substratum of earth still farther shoreward. Very much of the south shore of the lake shows such a formation. The ice beach near the outlet of Clear Creek is at least 30 inches above lake level and separates a dense swamp from the lake. In this swamp thus isolated from the main lake, the semi-aquatic plants readily establish themselves and thus finally reclaim the swamp land.

The plant life in the lake is abundant. A bank of *Scirpus* practically encircles the lake. *Nuphar, Nymphæa, Typha, Potamogeton, Ceratophyllum* and *Chara* are abundant. The outlet is now entirely "overgrown" by *Nuphar, Nymphæa, Typha* and *Scirpus* arranged in water zones.

The average temperature of the water from July 6th to August 23d, 1899, was 80 degrees at a depth of two feet; the air temperature for the same time was 81.5 degrees. The deep water of the lake marked 41 degrees, and was of course subject to no diurnal changes. The prevailing winds during the summer months are west to southwest.

THE COLD BLOODED VERTEBRATES OF WINONA LAKE.

By Earl E. Ramsey.

FISHES.

The number of species of fishes thus far secured in Winona Lake, its inlets and outlets, is 41. Considering the great variety of physical conditions, the number of species is small. But the number of individuals of each species is much more disappointing. The scarcity of the larger food fishes is due to the great amount of fishing in the lake. But the scarcity of the smaller fishes, the *Cyprinidæ,* many species of the darters, *Labidesthes,* etc., is not accounted for in this way.

To show the relative numbers of a very common form which serves as food for the larger species, I may take the *Labidesthes sicculus.* As many as a gallon of this form may be secured in either Turkey Lake or Tippecanoe Lake, Kosciusko County, at a single haul of the seine. Not more than three or four dozen were secured in Eagle Lake during the entire summer. The same relative proportions are true of many other forms.

The following list gives the species and localities from which they were secured. The column marked N* gives some notion of the relative abundance. Thirteen families are represented and 33 genera. The +'s in the other columns indicate the localities in which the various species are found.

	Cherry Creek.	Clear Creek.	Lake.	Outlet.	Tippecanoe River.	N.
Lampetra wilderi Gage	....	....	....	+	....	1
Lepisosteus osseus (L.). Common Gar-pike	....	....	+	....	....	1
Lepisosteus platostomus Raf. Short-nosed Gar	....	....	+	....	....	×
Amia calva L. Mudfish; Dogfish	....	....	+	....	....	—
Amieurus nebulosus (Le S.). Yellow Cat	....	....	+	....	....	×
Amieurus melas (Raf.)	....	....	....	+	....	2
Schilbeodes gyrinus (Mitch.). Slender Mud Tom	....	....	....	+	....	3
Carpiodes (sp........)†	....	....	+	+	....	2
Catostomus commersoni (Lacépède)	....	+	....	....	....	—
Catostomus nigricans Le S. Hog Sucker; Stone Roller	+	+	+	+	....	×
Erimyzon sucetta oblongus (Mitch.). Chub Sucker; Sweet Sucker.	....	....	....	+	....	×
Minytrema melanops (Raf.). Winter Sucker	....	+	....	....	....	1
Campostoma anomalum (Raf.). Stone Roller	+	+	....	....	....	+
Pimephales notatus Raf.). Blunt-nosed Minnow	+	....	+	....	....	+
Notropis whipplei (Girard). Silver-fin	+	....	+	+	....	+
Notropis cornutus (Mitch.). Silver-side; Shiner	+	....	....	+	....	×
Hybopsis kentuckiensis Raf.). Horny-head	+	+	....	....	....	—
Semotilus atromaculatus (Mitch.). Horned Dace; Creek Chub	+	+	....	+	....	+
Abramis chrysoleucus (Mitch.). Golden Shiner	....	....	+	....	..	×
Umbra limi (Kirtland). Mud Minnow	+	....	....	....	....	5
Lucius vermiculatus (Le S.). Little Pickerel	+	....	+	+	....	×
Fundulus notatus (Raf.). Top Minnow	....	....	+	....	....	+
Fundulus dispar (Agassiz). Top Minnow	....	....	....	+	....	—
Labidesthes sicculus (Cope). Brook Silverside	+	....	+	+	....	—
Pomoxis sparoides Lacépède). Calico Bass; Grass Bass	....	....	+	....	....	1
Ambloplites rupestris (Raf.). Red-eye; Goggle eye	+	....	+	+	+	+
Chænobryttus gulosus (Cuv. and Val.). War-mouth	+	....	+	+	....	×
Lepomis pallidus (Mitch.). Blue-gill; Blue Sunfish	+	....	+	+	+	+
Lepomis megalotis (Raf.). Long-eared Sunfish	....	....	....	+	+	×
Eupomotis gibbosus (L.). Common Sunfish	+	....	+	+	....	×
Micropterus dolomieu (Lacépède). Small-mouthed Black Bass	....	....	...	....	+	5
Micropterus salmoides (Lacépède) Large-mouthed Black Bass	+	....	+	+	+	+
Percina caprodes Raf.). Log Perch; Manitou Darter	+	....	+	....	+	×
Hadropterus aspro (Cope and Jor.). Black-sided Darter	+	....	+	....	+	3
Boleosoma nigrum (Raf.). Johnny Darter	+	+	+	+	+	+
Diplesion blennioides Raf. Green-sided Darter	....	....	....	....	+	2
Etheostoma iowæ Jor. and Meek Iowa Darter	+	....	...	+	....	—
Etheostoma cœruleum Storer. Blue Darter; Rainbow Darter	+	+	+	+	+	+
Microperca punctulata Putnam. Least Darter	....	....	....	+	....	—
Perca flavescens (Mitch.). Yellow Perch; Ringed Perch	+	....	+	+	....	×
Cottus ictalops (Raf.). Bullhead; Blob	+	+	....	+	....	+

BATRACHIANS.

This group is represented by but eight species, as follows:

1. *Necturus maculosus* Raf. Mud Puppy; Water Dog.

   Three or four specimens were found by workmen who were deepening the channel of Cherry Creek.

*In some cases the number of specimens collected is marked; + indicates that the species is abundant; ×, not so abundant; —, but few.

†Two large specimens taken by fishermen were seen. The species was probably *C. velifer* (Raf.), but no positive identification further than genus could be made.

2. *Bufo lentiginosus americanus* (Le Conte). American Toad.
3. *Acris gryllus gryllus* (Le Conte). Southern Cricket Frog.
4. *Acris gryllus crepitans* (Baird). Northern Cricket Frog.
5. *Hyla versicolor* (Le Conte). Common Tree Toad.

But two specimens of this interesting animal were gotten.

6. *Rana pipiens* Kalm. Leopard Frog.

This is the most abundant of the frogs.

7. *Rana clamitans* Latreille. Green Frog.

This species is nearly as numerous as *R. pipiens*.

8. *Rana catesbiana* Shaw. Bull-frog.

But one or two specimens found.

SNAKES.

Eight species of snakes have been found in the vicinity of the lake.

1. STORERIA DEKAYI (Holb.). Dekay's Brown Snake. Rare.
2. CLONOPHIS KIRTLANDI (Kennicott). Kirtland's Snake.

Only two or three specimens were taken.

3. THAMNOPHIS SIRTALIS PARIETALIS (Say.).

3a. THAMNOPHIS SIRTALIS SIRTALIS L.

These two varieties of the garter-snake are the most abundant of the forms found in the vicinity of the lake. On July 19th, a female bearing 30 well developed embryos was killed. On August 5th, one kept in a pen gave birth to young, the number of which could not be ascertained.

4. REGINA LEBERIS (L.). Leather Snake; Queen Snake.

The leather-snake is abundant in the locality of the lake, being perhaps third in point of number. On August 12th, 1899, a gravid female was found having 10 well developed embryos. Its haunts are along creeks.

5. NATRIX SIPEDON (L.) Water Snake.

This form is plentiful. On July 23, 1900, a female containing 26 embryos was killed. The water-snake is a swamp-loving form, and is of a sullen, vicious disposition.

6. **Bascanion constrictor (L.). Blue-racer; Black Snake.**

This is the largest snake in the vicinity of the lake, and is comparatively abundant. When captured and put in a pen, it soon tames and seems to take delight in being handled. Its movements and shape are peculiarly graceful. Its food consists of frogs, garter-snakes, etc. A specimen 42 inches long swallowed a garter-snake 28 inches long. I have known it to lay its eggs about the middle of June and have found the young hatching about the middle of September. Its egg-laying habit is worthy of note. One specimen selected the soft ground between two rows of potatoes and pushed her way under the ground. As she crawled along in this underground passage, the eggs, 22 in number, were lain in the channel which her body had made. Another laid her eggs in the hollow root of a half decayed stump.

The eggs are white in color, are about an inch in length and have a uniform diameter of about one-half inch. The soft shell is so tough that it will sustain a weight of more than 100 pounds without breaking. The young, when first hatched, are seven or eight inches in length. The first action when the little head is thrust through the leathery shell is to stick out its tongue. The blue racer frequents the woods or high grass and weeds.

7. **Lampropeltis doliatus triangulus (Boie.). Milk Snake; House Snake.**

This species is found rarely.

8. **Sistrurus catenatus (Raf.). Prairie Rattlesnake.**

The prairie rattlesnake is second in point of numbers, the garter-snake being more plentiful. During the summer of 1899, eleven specimens were caught, and nine were taken during the following summer. They are usually found in low land and run but little during the day unless disturbed. Nothing was learned concerning their food, since they persistently refused to eat when kept in confinement. A female kept in a pen gave birth to seven young on August 13th. Several of the little ones were kept in a glass aquarium for a time. On August 17th they drank some water and were given small bits of fresh meat. Three days later they began their first moult. They were about eight and a half inches long at birth. A case was reported to me in which 13 young were born. The adults are inoffensive, and move slowly. They are easily captured by means of a noose slipped over their head or by an insect net.

TURTLES.

The land and water forms together number eight species. Of these, the soft-shelled turtle, the speckled tortoise, Blanding's tortoise and the box tortoise are rare. Even the commoner species are not very abundant. No more than two dozen eggs were found. They were those of the stink-pot, *Aromochelys odoratus* (Latreille), and were laid in heaps of debris which had been washed up along the shore. The species are as follows:

1. *Aspidonectes spinifer* (Le S.). Common Soft-shelled Turtle.
2. *Chelydra serpentina* (L.) Common Snapping Turtle.
3. *Aromochelys odoratus* (Latreille). Musk Turtle.
4. *Graptemys geographicus* (Le S.). Map Turtle.
5. *Chrysemys marginata* (Agassiz). Lady Turtle.
6. *Clemmys guttata* (Schneider). Speckled Tortoise.
7. *Emydoidea blandingii* (Holb). Blanding's Tortoise.
8. *Terrapene carolina* (L.). Common Box Turtle.

MARL.—The largest body of marl appears to lie along the north shore and in the embayment in the northeast corner. Except near the ice house on the northeast shore the marl, at practically every point tested in the area mentioned, extended below depth of drill. There would seem to be 50 acres of marl in that area in less than 15 feet of water. South of the embayment mentioned is an area of low ground underlain with marl. Rounding the point and running south the marl occurs along the shore with a good width and depth until the Indiana University Biological Station is reached where, for a distance past the mouth of an inlet from the east, the bottom is sandy. Along most of the south end of the lake the belt of shallow water marl is broad and the marl below reach of pole. At the edge of the water the marl appears to be replaced with muck. In the southwest corner of the lake the bottom is sandy. South of the center of the lake is a shoal of 10 or 15 acres of shallow water over which the bottom of marl was below reach of drill. Along the north half of the west shore the marl sets in, but over a very narrow belt. Passing through the "Narrows" one enters a small bay or arm in which the marl occurs all around the shore in a belt of medium width and at most points tested was over 16 feet in thickness. Apparently some of the low land adjacent to this bay is underlain with marl but it was not tested. All told, there appears to be 75 to 100 acres of shallow water marl, most of which extends over 16 feet below the water level.

The quality of the marl, while variable, generally appeared good, that toward the northeast being the best.

HUFFMAN LAKE.

LARGE DEPOSIT, MOSTLY UNDER DEEP WATER.

This lake occupies parts of sections 30 and 31 (33 north, 5 east), Prairie Township. It lies half a mile northwest of the village of Atwood and a quarter of a mile or less from the Pittsburg, Ft. Wayne & Chicago Railway. The lake was lowered four feet in the summer of 1899. The former water area, according to the county atlas, was about 250 acres. The present area is probably 75 or 100 acres less. Due to the lowering of the lake the present water area is everywhere surrounded by a broad bench running from 200 to 300 feet wide or over. The waves are already at work leveling this off so that at most points the bench ends abruptly at the water's edge in a perpendicular

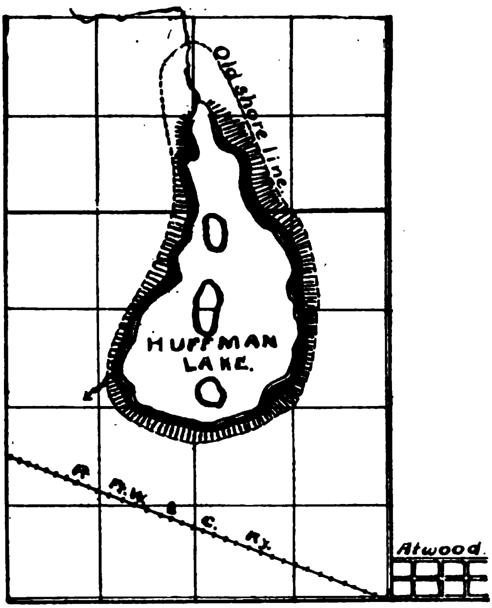

Fig. 54. Map of Huffman Lake, Kosciusko County, Ind.

or partly undermined bank a foot or two high and extending to just below the water level. Back of this bench, at the north, occurs a broad and extensive marsh; at the south, low ground, while at the east and west the banks rise gradually into upland of moderate height. In the lake the water at every point becomes deep only a yard or two from the bluff described above. Three small islands rise six to eight feet above the water in the south part of the lake.

MARL.—The lowering of the lake has brought the surface of all of the former shallow water marl above the present water level. This forms the bench described above, at all points except at the extreme north end of the lake. Toward the shore this bench tends to become mucky. Sometimes the surface of clean marl forms the larger part of the bench, as at the southeast corner, while again, as along the northwest shore, the marl is exposed over only a part of the bench. Thus near the southeast corner the old shore line was 300 feet back of the present line and there the muck starts in a few inches deep. Going out the muck runs out and the marl increases in depth until half way between the old and new shore lines the marl is 16 feet deep. Further north in places the depth increases more rapidly so that 16 feet of marl is found only 75 feet from the old shore line, and 225 feet from the new. At the north end of the lake no marl is exposed and as far as drilled only a marly muck occurs. Along the west side the band of marl seems much narrower and the muck increases rapidly in depth from the edge of the exposed marl. Thus at one point, 15 feet from the inner edge of the exposed marl, the muck was found to be almost 10 feet deep, while below that was marl to beyond depth of auger. The three islands appear to be wholly composed of marl.

The quality of the marl did not appear of the best, it being a dark gray. The cutting of the water exposes well the shells in the marl, and the penetration of the *Chara* roots, in many cases the roots running into or through the shells. The amount of marl with surface exposed or in shallow water is not sufficient for manufacturing purposes. If the entire lake were drained, or if facilities are obtained for securing the deep water marl, a workable deposit will doubtless be found.

SILVER LAKE.

NOT A WORKABLE DEPOSIT.

Silver Lake lies in section 6 (30 north, 6 east), a little west of Silver Lake station on the Michigan Division of the Big Four Railway. It has an area of about 125 acres. The surrounding hills are about 15 to 20 feet high with much flat land but little above the lake level, especially on the southwest. The lake has been lowered a little, so that deep water sets in close to the present shore line.

MARL.—Along the side of the water's edge the marl runs from nothing to a maximum of 13 feet, being 13 feet deep at (A), nothing at (B), then thickening up to 12 feet at the boat houses at (C). It

evidently extends back several rods but with increasing cover. At the south end of the southeast lobe only muck was found. From (D) to (E) the deep water sets in about 20 feet from shore. Here the marl runs from 10 to over 16 feet deep. South and west of this is

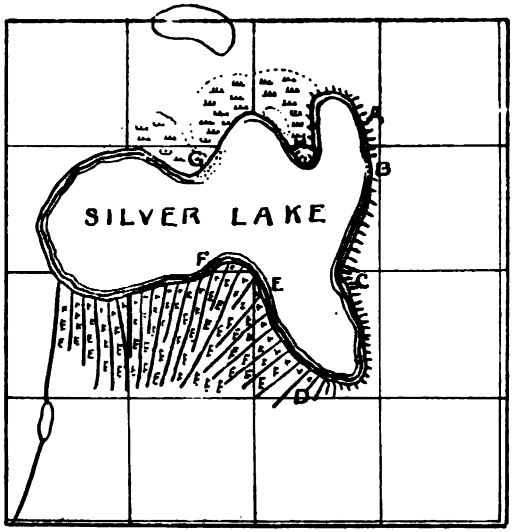

Fig. 55. Map of Silver Lake, Kosciusko County, Ind.

a flat area, probably exceeding in size the area of the lake, which consists of marl overlain by muck. At the shore the muck is about six inches deep; 300 feet back from shore the muck has increased to four feet with 10 feet of marl below. Marl is reported to have been struck down the outlet under from two to four feet of muck. North and west of (F) and south of (G) the marl is over 16 feet deep, though available over only a very narrow strip. Just east of (G) the marl runs a foot thick in water from one to six feet deep. At (H) the marl is again deep.

This can not be considered a workable deposit.

FULTON COUNTY.

References.—

1859.—Richard Owen, Geol. Reconn. of Ind., p. 217.

1875.—G. M. Levette, 7th Ann. Rep. Geol. Surv. Ind., p. 474.

1899.—Frank Leverett, Water Supply and Irrigation Papers, U. S. Geol. Surv., No. 21, p. 46.

Fulton County is located near the center of the northern half of Indiana. It is in the third tier of counties south of the Michigan-

Indiana line and is bounded on the north by Marshall, on the east by Kosciusko, Wabash and Miami, on the south by Miami and Cass and on the west by Pulaski County. In outline it is very irregular, the south and east sides being dove-tailed in with some of the townships of the adjoining counties, in a very peculiar manner. The total area of the county is 380 square miles.

The surface is everywhere covered with drift and is very diversified. The Maxinkuckee moraine covers the northern third of the county, while the eastern and southeastern portions are covered by the western slope of a bulky moraine formed by the Erie lobe. These two moraines connect in the northeastern part of the county to form the great Erie-Saginaw interlobate moraine which passes northeastward into Michigan through the northeastern part of Indiana. The thickness of the drift is known only at Rochester, where it ranges between 155 and 245 feet, and at Kewanna, where it is between 167 and 208 feet.

The county lies on the southeastern extremity of the prairies which cover a great part of the northwestern counties of the State. These prairies lose themselves in the oak openings, and disappear almost entirely after the center of Fulton is reached. Nearly fifteen per cent. of the surface is prairie; the remainder is pretty equally divided between oak openings, or barrens, and heavy timbered lands. The surface is level, as a rule, but broken into considerable hills in Henry Township in the eastern and in Richland in the northern part.

The principal stream is the Tippecanoe River, which enters from Marshall County in the northeast, and, curving south some five miles, it leaves near the northwest corner, flowing into Pulaski County. Mill and Mud creeks, the former the outlet of Lake Manitou, and the latter of the Mud Lakes, are the principal tributaries of the Tippecanoe in the county. Chippewa-Nuck, rising in Henry Township, and another stream, also known as Mill Creek, in Wayne Township, are creeks of some size, and flow, also, into the Tippecanoe. West of Rochester there is much marsh land with sandy ridges, which is imperfectly drained by Mud Creek and other streams and ditches, into the Tippecanoe.

The county is well supplied with railways, three passing entirely through it. These are: The Michigan City Division of the Lake Erie & Western, which passes north and south through the central portion; the Chicago & Erie, which enters the county near DeLong in the northwest corner, passes through Rochester, where it crosses the L. E. & W., and leaves the county at the extreme southeastern

corner, thus passing diagonally across its bounds; and the Michigan Division of the Vandalia, which runs north and south a few miles east of the western boundary, passing through Kewanna and crossing the C. & E. at DeLong. The following is the altitude in feet above tide of the principal stations along these railways: Akron, 858; Bruce Lake, 776; DeLong, 748; Germany, 750; Kewanna, 786; Leiters, 745; Rochester, 779; Tiosa, 826.

The lakes of Fulton County are few in number and are as far south as any in the State. There are several of small size about Akron which we did not find time to visit and which may contain marl in sufficient quantity for commercial use.* Of the lakes visited and described on the pages which follow, only Manitou contains a marl deposit of workable size.

MANITOU LAKE.

WORKABLE DEPOSIT.

This large and beautiful lake lies southeast of the city of Rochester, its northwestern shore being about one mile from the corporate limits. It occupies parts of sections 10, 11, 15 and 16 (30 north, 3 east), Rochester Township. The extreme length, from the outlet at the northwest corner to the inlet at the end of the southeastern lobe, is about two and one-fourth miles and the greatest width a little more than one and one-fourth miles. The present water area, according to careful computation by Mr. Hugh B. Holman, who prepared the accompanying map, is 886¾ acres.

Three or four separate bodies of water are now comprised in Manitou Lake. These were united and their total water area greatly increased by a dam which was first constructed across the outlet in 1830.† This dam raised the water level about seven feet, and so covered the intervening areas of low ground between the several smaller lakes. The greater portion of Manitou Lake is therefore covered

*For detailed information concerning the marl deposits about Akron anyone interested can write Mr. J. J. King, who has given the matter some attention.

†This data was furnished by Dr. Vernon Gould, who wrote under the date of December 24, 1900, as follows: "The original dam at the foot of the lake must have been built about 18 0. It was built by the U. S. Government and a mill erected there for the use of the Pottawottomi Indians, who had, at that time, a village and cornfields west of the lake. After the removal of the Indians west of the Mississippi, about 1836, the dam was disconti ued and a dam built lower down the stream at the town site of Rochester, then just laid out and plotted.

"Later, about 1850, the dam was rebuilt at the lake and the water raised as a reservoir, the water being taken from the lake by an artificial race to the mill in Rochester. This mill was burned three years since and has not been rebuilt. No use is made at the present time of this water power below the lake."

with shallow water, much of which is not over five feet in depth. The deepest water occurs south of Long Island, where one sounding in August, 1900, showed 49 feet. The main inlet, Mill Creek, is a small sluggish stream, which enters the lake near its extreme southern end. White's Creek, still smaller, enters the east side opposite Long Island. The outlet flows about four miles northwestward and empties into the Tippecanoe River.

According to Dr. G. M. Levette: "At the time white men first visited this section of country it was inhabited by the Pottawottomi Indians, and from that tribe came the name of the lake and the legend which gave rise to it. They believed this body of water to be the home of "*Manitou*," or "Bad Spirit;" that during heavy storms and certain nights in the dark of the moon, he might be seen disturbing and tossing the water, and, in defiance of repeated warnings, a number of dauntless "braves" of the tribe, who ventured to the shore of the lake after nightfall, were never heard of afterward. So firm was their belief in this musty and absurd tradition, they would not venture upon the lake in canoes, or eat fish taken from it."*

The word "Manitou" among certain of the American Indians signified spirit or other object of religious awe or reverence. Two manitous or spirits are spoken of in Indian traditions—one the spirit of good, the other the spirit of evil. The latter must have been the one from which Lake Manitou was named, as Dr. Gould states that "it was also known as 'Devil's Lake' to the Indians and to all the early settlers. Most of the latter believed 'Manitou' means 'Devil.' The Devil was even reputed to have been seen by some of these early settlers, especially when they had snakes in their boots."

The shores of the lake have lost much of their primitive beauty on account of the destruction of timber formerly covering the bordering territory. They are much diversified in character, being, for the most part, low and marshy. In places, however, they rise 15 to 40 feet above the water level and are prettily wooded with oak and other timber. This is especially true of a stretch on the east shore above and below the East Side Hotel. Here the bank rises abruptly and the wooded grove on its crest offers fine sites for cottages—a number of which have been erected. The bottom of the lake bordering this stretch is of gravel and affords fine facilities for bathing, the water increasing gradually to 10 feet in depth 50 feet from shore.

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* Loc. cit., p. 475.

Three wooded islands, Coney, Long and Round, rise 10 to 15 feet above the water level. Coney Island has one or two buildings upon it and is quite a resort for a certain element of Rochester's population. The other two are often occupied as fishing camps. West and south of Long Island are the remains of many oak stumps and logs in water three to five feet deep, showing that the area of the island was formerly much larger than at present. Southwest of Round Island is an extensive marsh known as the Goose Pond. Its bottom is of muck, and the water only from one to five feet in depth. The spatterdock or yellow pond lily, *Nymphæa advena* Soland, and immense numbers of cat-tails, *Typha latifolia* L., flourish there, and so clog the waters that they are impassible for a boat. By their decay they are slowly adding to the thickness of the muck so that but a few years will elapse until this portion of the lake will become a muck meadow. Now it is the abiding place of myriads of muskrats and, in spring and autumn, the temporary home of thousands of water fowl.

A lake possessing so large a shallow water area as does Manitou, is always productive of an extensive aquatic flora. A number of species of pondweed, *Potamogeton*, flourish everywhere in water under 10 feet, and their flowering and fruiting tips rise above the surface and are swayed by every passing breeze. The water weed or ditch-moss, *Philotria canadensis* (Michx.), abounds beneath the surface of all the bays and at the mouth of the inlets. The eel grass, *Vallisneria spiralis* L., famous food for ducks, grows around the edges of the deeper water of the original lakes, its curiously coiled, fruiting stem showing prettily through the clearer depths. Two or three species of rushes, *Scirpus*, form wide belts of vegetation in many parts of the lake, being especially common along the shelving margins of the original lakes. The peltate leaves of the water shield, *Brasenia purpurea* (Michx.), float placidly and reflect the sunshine from their dark green surface in many places, while great patches of the bottom here and there are carpeted with the waving plumes of *Chara*. Scores of other plants abound within or about the margins of this lake, those mentioned being only the ones which caught our notice during a hurried reconnaisance of the marl resources of its bottom. One could with profit spend an entire season, if not several of them, in studying and making a permanent record of its flora, paying especial attention to the zone of depth in which each species grows, and grouping those of each zone in its proper class.

The fish fauna of the lake is well worthy of mention as it attracts hundreds of anglers each season. The first 19 species of the following list were taken from it in one day a few years ago by Messrs.

Eigenmann and Norman. The remaining five species are said to occur therein by Dr. Vernon Gould, who for years has given special attention to the geology, flora and fauna of Fulton County.

LIST OF FISHES KNOWN TO OCCUR IN LAKE MANITOU.

1. *Polydon spathula* (Walbaum). Spoon-bill Cat; Duck-bill Cat. One weighing 114½ pounds was taken from the lake some years ago.
2. *Lepisosteus platystomus* Raf. Short-nosed Gar-pike.
3. *Ameiurus natalis* (Le S.). Yellow Cat.
4. *Erimyzon sucetta oblongus* (Mitch.). Chub Sucker; Sweet Sucker.
5. *Pimephales notatus* (Raf.). Blunt-nosed Minnow.
6. *Notropis whipplei* Girard. Silver-fin.
7. *Hybopsis kenturkiensis* (Raf.). Horny Head; River Chub; Jerker.
8. *Zygonectes dispar* Agassiz. Top Minnow.
9. *Umbra limi* (Kirtland). Mud Minnow.
10. *Lucius vermiculatus* (Le S.). Little Pickerel.
11. *Labidesthes sicculus* Cope. Brook Silverside.
12. *Pomoxis sparoides* (Lacépède). Calico Bass; Grass Bass; Croppie.
13. *Lepomis pallidus* (Mitch.). Blue Sunfish; Blue-gill; Dollardee.
14. *Lepomis heros* (B. and G.). Chain-sided Sunfish.
15. *Lepomis gibbosus* (L.). Common Sunfish; Bream; Pondfish; Pumpkinseed.
16. *Micropterus salmoides* (Lacépède). Large-mouthed Black Bass; Green Bass.
17. *Etheostoma blennioides* Raf. Green-sided Darter.
18. *Perca flavescens* (Mitch.). Yellow Perch; Ringed Perch.
19. *Cottus bairdi* (Girard). Miller's Thumb; Blob; Muffle-jaw.
20. *Amia calva* L. Dogfish; Mudfish.
21. *Ictiobus cyprinella* (Cuv. and Val.). Buffalo Fish. Said to reach a weight of 65 pounds.
22. *Coregonus artedi* Le S. Cisco; Lake Herring. Inhabit only the deeper waters, except in late autumn, when they visit the shoals.
23. *Esox lucius* L. Pike. Formerly common, but now rarely taken.
24. *Chænobryttus gulosus* (Cuv. and Val.). War-mouth; Indian Fish.

Eight species of turtles occur in and about Manitou Lake. Representatives of all were seen by the writer, either in the lake or in the collection of turtle shells made by Dr. Gould. This number is exceeded only at one other lake in the State, viz., Bass Lake, Starke County, where one additional species is known to occur. Those found at Manitou Lake are as follows:

1. *Aspidonectes spinifer* (Le S.). Common Soft-shelled Turtle.
2. *Chelydra serpentina* (L). Common Snapping Turtle.
3. *Aromochelys odoratus* (Latreille). Musk Turtle; Stink-pot.
4 *Malaclemmys ge graphicus* (Le S). Map Turtle.
5. *Pseudemys elegans* (Weid.). Elegant Terrapin.
6. *Chrysemys marginata* (Agassiz). Painted Turtle; Mud Turtle.
7. *Clemmys guttatus* (Schneider). Speckled Tortoise.
8. *Emys meleagris* (Shaw). Blanding's Box Tortoise. This and the last named species are more often found in the ditches leading into the lake than within its actual water area.

The mollusca of the lake appeared to be few in number of species. But little attention was, however, given to them, the following bivalves alone being noted: *Unio iris* Lea; *U. subrostratus* Say; *U. luteolus* Lam.; *Anodonta footiana* Lea and *A. grandis* Say, all of which were common.

MARL.—The testing of Manitou Lake for marl was more thorough than in most other lakes, Mr. Blatchley having put down 60 bores in May, 1900, and Mr. Hugh Holman 137 at a later date. The results show that the area covered by the original lakes is all underlain with marl, the thickness of the deposits ranging between one and 19+ feet, the length of the auger used being 22 feet. In but a few places was marl found in water less than four feet deep, the bottom being of muck and sand, and no marl occurs in one and two-foot water. Marl was almost everywhere present beneath four-foot water, 47 out of 66 bores put down at that depth finding it ranging in thickness up to 18+ feet. Fourteen of the 47 did not reach the bottom of the deposit, while the average thickness of the deposit pierced by the 33 bores reaching bottom was 7.8 feet. In all water over four feet, within the bounds of marl territory shown on the map, marl was found, and by far the greater number of bores did not reach bottom, thus showing that it occurs only within the limits of the original lakes. The best deposit, but not the most available, probably occurs in what was formerly Clear Lake, in the southwestern corner of the main body of the present water area. This lake had an area of 80 or more acres, and everywhere in four to six feet of water about its former margin the marl was beyond the depth of the auger and of a fine quality. About twenty-five acres of this deposit is at present available, the remainder being beneath water 10 to 39 feet in depth. There is not much shallow water in the long southern lobe of the lake below Long Island. The four-foot water-line along the west shore is about 100 feet from the margin of the lake and the bottom usually shelves off rapidly into deep water. About the margins of

Round Island several bores showed marl to be 16+ feet in six-foot water, while in four-foot water it was reduced to 10 feet with gravel beneath. Half way down the south lobe and about 200 yards east of the west margin "a blind island" or shoal several acres in extent comes within a few feet of the surface. Here the marl is everywhere below reach of auger in four to 17 feet of water. For a long distance north of the inlet the southern lobe is choked with vegetation underlain with deep muck. Along the east shore opposite the hotel and cottages, the 10-foot water line is only 40 to 50 feet from the margin of the lake. Marl sets in in six to eight feet of water and in water over 12 feet the bottom of the deposit was beyond reach of the auger.

East and north of Long Island the shallow water area is wide, in places extending out 700 feet from shore. In all places tested the marl is over 10 feet thick in five-foot water and, within the limit line shown on the map, but few bores were put down in which the bottom of the deposit was reached, and they were close to the shore of the lake or island in three and four-foot water. The quality of the marl in this region is not so good as in Clear Lake and the area west of Long Island, it being darker in color and coarser grained. In some places the marl is overlain by one to three feet of muck.

West of Long Island and north of the east-west section line is a large area of water from four to 20 feet in depth which is almost everywhere underlain with marl. No bore in water over five feet reached the bottom of the deposit, while most of those in four and five feet of water found the deposit to be 10 to 14 feet in thickness. Along the north shore, for 100 to 350 feet out the bottom is for the most part of gravel and the water less than four feet in depth. Mr. Holman has computed the total area of marl in the lake to be 519¼ acres. Of this fully one-half is beneath water less than 10 feet in depth. The average thickness of the deposit, as shown by the 137 bores put down by him, was 10.34 feet, but it must be remembered that most of his tests were made in shallow water, so that the average depth of the entire deposit is much greater.

An analysis of an average sample of the marl from Manitou Lake showed its composition to be as follows:

Calcium carbonate ($CaCo_3$)	87.65
Magnesium carbonate ($MgCo_3$)	2.60
Alumina (Al_2O_3)	.19
Ferric oxide (Fe_2O_3)	.30
Insoluble inorganic matter (silica, etc.)	6.39
Organic matter	2.88
Total	100.01

This shows the quality of the marl to be in every way suitable for the manufacture of Portland cement. The percentage of insoluble silica is rather high, but as silica is one of the ingredients of the clay used as a factor of the cement it is not harmful. It must be remembered that the samples were obtained and brought up by the auger, and in passing through the surface of the marl deposit were liable to be mixed with diatoms and other siliceous impurities. Samples taken in another manner, from the midst of the deposit and carefully kept from all impurities would without doubt show a higher percentage of carbonate of lime.

Finally, it may be said that the marl deposit of Maintou Lake is well worthy the attention of capitalists. Its area, thickness, and availability are all excellent. It lies within one-quarter of a mile of the Lake Erie & Western and within three-fourths of a mile of the Chicago & Erie railways, which furnish excellent transportation facilities in all directions.

NORTH AND SOUTH MUD LAKES.

Deposit of Doubtful Workable Size, Partly Under Deep Water.

These two lakes lie in sections 15, 16, 21 and 22 (29 north, 3 east), Liberty Township, eight miles south of Rochester and three miles west of the L. E. & W. Railway. By the encroachment of decaying vegetation and by draining, their water area has been reduced more than one-half within the past 20 years.

NORTH MUD LAKE.

This lake has at present a water area of only 60 acres. It is about 160 rods long by 40 to 60 rods wide and is divided into two lobes, which are connected by a channel 75 feet wide by 300 feet in length. The upper and larger lobe has low marshy shores on its east and north sides. About the inlet which enters near the middle of the east shore the marsh extends back for a long distance, forming an area of 60 or more acres. This was formerly covered with water and comprised a portion of the lake shown on the older maps. The banks of the west shore rise 20 to 30 feet, back 10 or more rods from the water's edge, a marsh intervening, except on the south half, where the bluff rises close to the water. The margins of the water contain many rushes, spatterdock and other aquatic plants. The south lobe comprises about 25 acres of water with high cultivated banks on the north and west and low marshy ones on the south and east. The marsh on the east is, however, not more than 20 rods wide and then

rises into sloping wooded hillsides. The maximum depth of water in the lake is 50 feet and the shallow water area is everywhere very narrow.

Along those portions of the water margin of this lake on the east and north shores, which bordered the tracts of bare marsh marl were myriads of the dead shells of small univalve mollusks. They had been thrown up by the waves into ridges, several inches thick and a foot or two wide. This was the only lake where such an accumulation of univalve shells was noted, and it is possible that in the past their remains have contributed largely to the formation of the surrounding and underlying marl. A pint or so of the shells were scraped up, and their determination discloses the following species. The approximate relative abundance of each as represented in the mass collected, is also given:

Limnophysa desidiosa Say	4 per cent.
Limnophysa humilis Say	2 per cent.
Physa heterostropha Say.	12 per cent.
Helisoma trivolvis Say	5 per cent.
Helisoma bicarinata Say	3 per cent.
Menetus exacutus Say	1 per cent.
Gyraulus parvus Say	12 per cent.
Amnicola limosa Say	20 per cent.
Amnicola cincinnatiensis Anthony	20 per cent.
Amnicola lustrica Say	10 per cent.

Remains of broken shells, in part species of *Sphærium*, undeterminable, made up the remaining 11 per cent. It will be noted that the three species of *Amnicola* make up 50 per cent. of the mass collected. Of these *A. lustrica* has not heretofore been collected in the State.

MARL.—At Minter's boat landing on the east side, near the north end of the south lobe, the bottom is of muck 20+ feet thick, and shelves rapidly, 20-foot water being found 50 feet from shore. One hundred yards northwest, on the south shore of the point of land separating the two lobes, the marl forms the bottom, being 20+ feet thick in two-foot water, and seven feet thick at shore. On the east side of the north lobe south of the inlet, the marl at the shore is 15 feet thick, and 75 feet back is three feet thick, there being probably five acres of marsh underlain with shallow depths of marl. North of the inlet for 30 or more rods deep muck only occurs in all the shallow water area. Marl then sets in again, being seven feet thick in four-foot water and beyond reach of auger in 10-foot water. A short distance farther on it forms the surface of several acres of marsh, being 10 feet thick at the shore line and 12 feet thick 200 feet back, after which muck begins to cover it and rapidly thickens. The

northeastern corner of this lobe of the lake is also bordered by a strip of marsh marl, 200 yards long by 150 feet wide which runs from 20+ feet in thickness at shore to 0 at the eastern side. Along all of the north and west shores muck 12+ feet thick forms the bottom of all water less than 15 feet in depth, except in a few places, where shallow deposits of marl occur. Along the west side of the south lobe the shallow water area is only 15 to 25 feet in width and is underlain with marl five to eight feet thick, with sand beneath. The bottom along the south shore is wholly of deep muck. The south half of the east shore is bordered with marl which at shore line is 15 feet thick. Marl also forms the surface of the marsh between the water and the wooded slope, for 150 feet back, where it is six feet thick. Muck then sets in and forms the surface to the base of the hills.

There is probably 25 acres of available marl 10 to 12 feet in average thickness on this lake and probably as much or more beneath its deep water. The large marsh east of the mouth of the inlet was not tested, except along its margins, where it was wholly of muck.

SOUTH MUD LAKE.

The north line of the water area of this lake is within a quarter of a mile of the southern end of North Mud Lake, a low divide intervening which formerly could be crossed with a boat during high water. The lake now contains about 50 acres of water, with a marsh of equal or greater area bordering the northeast shore. The present water area is elliptical in shape, its shores everywhere low, and bordered with marsh. A small island covered with underbrush is located near the center of the northern half, and just north of this the maximum depth of water, 26 feet, occurs. The water is much more turbid than in the North Lake, containing myriads of the lower forms of vegetable life.

MARL.—At the boat landing on the east side, one-third of the distance from the south shore, marl forms the surface of the marsh for 50 to 75 feet back from the water's edge, and averages 10 feet in thickness. The bottom of the shallow water area all around the south half of the lake is, however, mostly of muck. Fifty feet out from shore the water is usually 16 to 20 feet in depth. The north half has a wider shallow water area about its margins which is usually underlain with marl. Near the northwest corner there is a marsh area of two or three acres on the west shore which is composed wholly of marl 12 to 16 feet in thickness. The island at the center of the north half is surrounded by marl 10+ feet thick in eight feet of

water, and seven to 10 feet thick at the water's edge. East of the island along the eastern shore of the lake the marl runs from 10 feet in thickness in one foot of water to beyond 15 feet in three feet of water. As far as could be ascertained the large marsh to the northeast of the lake is covered with deep muck. Along the north shore of the lake the marl forms the surface over a strip 150 feet wide and 300 yards long, being 10 to 15 feet in thickness at the edge of the shore and gradually thinning out to the northward.

The area of available marl in the south lake is less than in the north one. If the two lakes were drained so that their depth would be everywhere below 10 feet, there is little doubt but that a workable deposit would be disclosed and the greater thickness of the marl bed would counterbalance its small acreage.

MARSH DEPOSITS NORTH AND NORTHWEST OF ROCHESTER.

NOT OF WORKABLE SIZE.

Several beds of marl occur in marshes north and northwest of Rochester. Of these two were visited.

SMITH DEPOSIT.

On the land of Jerry D. Smith, southeast quarter of the northwest quarter of section 31 (31 north, 3 east), one-third of a mile south of the Tippecanoe River and two miles northwest of Rochester, marl occurs beneath the marsh of a valley which was formerly occupied by a small lake. The marl averages 16+ feet in thickness over an area of 10 to 12 acres. Over the larger part of this area muck one to four feet thick overlies the marl. The latter is of excellent quality and was, in the early settlement of the county, burned into lime.

SISSON & MILLER DEPOSIT.

Seven miles northwest of Rochester, on the land of Chas. Sisson and Peter Miller, in the northwest quarter of the northeast quarter of section 21 (31 north, 2 east), there is a small lake, surrounded by a wide marsh, both of which are partly underlain by a thick deposit of a good quality of marl. Fifteen bores were put down about 10 rods apart in the marsh or at the edge of the water, no boat being available. All of these found marl which varied in thickness from two to 18+ feet, the latter being at the water's edge. The marl in the marsh is generally overlain with muck from six inches to two feet thick. From indications about the shores, the present water area of 15 acres is all underlain with a thick bed of marl, there being 35 to 40 acres in the entire deposit.

BRUCE'S LAKE.

Not a Workable Deposit.

This lake, formerly noted for its beauty and its fine fishing facilities, is now a desolate stretch of water bordered by bare, gravelly shores, and in many places choked by aquatic vegetation. These changes have mainly been brought about in the past three years by a dredged ditch on the west side of the lake which has drained off its water into the Tippecanoe River. The lake, as outlined on the maps of 10 years ago, occupied parts of sections 6 and 7 (30 north, 1 east), Union Township, Fulton County, and section 1 (30 north, 1 west), Harrison Township, Pulaski County. That portion in Pulaski County and at least one-third of that in Fulton County, is now a marsh.

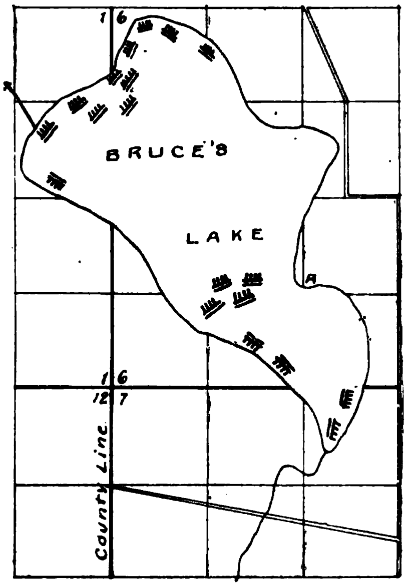

Fig. 56½. Map of Bruce's Lake.

The immediate shores of the lake are, for the most part, low, and the shallow water area is now wide. Only on the north half of the east side do the gravelly banks rise any distance above the water level. Here they are 30 feet high with a gravelly plain 10 to 15 rods wide intervening between them and the lake. On the northeast shore the gravel banks slope gradually up 15 to 20 feet above the water and a small timbered area, the only one about the lake, lies back of them. The giant bulrush, *Scirpus lacustris* L., extends out 250 or more feet from the shore, the six-foot water line being that distance out. The west half of the north shore, for 40 rods out in places, is a vast muck bed, over which flourishes a thick growth of cat-tail flags, *Typha latifolia* L. The north half of the west shore is similarly belted with a growth of cat-tails, about three rods wide. Back of this belt the bare hills of gravel and clay rise 10 to 15 feet. Opposite the point of land extending out from (A) the lake is almost filled with muck and aquatic plants and it will be but a few years before the smaller southern lobe is wholly separated from the larger one to the north. This southern lobe is now not over 40 rods wide and the deepest water found in it was 18 feet at several points near

its center. The extreme southeastern bay is about 30 rods in average width, and the water ranges up to 15 feet in depth. The eastern shore of this portion, as well as of the main body of water, is everywhere bordered with rushes which, on an average, extend out 10 rods from the water's edge, though in one place north of (A) they extend out 40 rods. The maximum width of the main body of the lake is about one-half a mile, and its greatest depth, in October, 1900, was 26 feet.

Bruce's Lake has long been noted as an excellent fishing resort. Black bass, blue-gills, cat-fish, war-mouth, goggle-eye, sunfish, perch and occasionally a pickerel, were caught before the lake was lowered. Since then all kinds of fish have been growing gradually fewer in number, and many of the fishermen who formerly sought its bounds with an assurance of a good catch now cast their lines in more distant lakes. Water fowl, too, were then abundant. Being distant from any other lake, most of the migratory ducks, geese, snipe and rails, passing anywhere near its surface, stopped to feed or to float on its quiet waters, and many hunters were attracted thither in autumn and spring. At the present annual rate of decrease of its water area, but a few years can elapse before this Mecca of fishermen and hunters will be wholly a marsh of cat-tails and rushes. A score of years will see it changed into a vast acreage of corn-producing land—which change is doubtless what the gold-seeking land owners, who have begun the drainage of its waters, most fervently desire.

Marl.—The marl in Bruce Lake, where it occurs at all, is a long distance from the present shore line and is mostly overlain with muck. Numerous tests along the north half of the east shore, 150 to 250 feet out, at the six-foot water line, showed muck eight feet, marl 4+ feet. Along the east half of the north shore sand only occurs beneath three-foot water 200 feet from shore; but in six-foot water 300 feet out, the marl was 12+ feet thick and dark in color. The west half of the north shore is a muck bed, as above stated. Along the west shore marl four to 8+ feet thick is found in a few places beneath muck of varying thickness, but for the most part muck only occurs beneath all water less than 10 feet in depth. The same conditions prevail in the shallow water around the southern lobe, the muck being almost everywhere beyond reach of 18-foot auger. Beneath shallow water in the middle of the lake opposite (A) marl was found beneath six to eight feet of muck, but it was of a yellowish cast, due to the seepage through the overlying muck. While the deeper waters of the lake may in places overlie isolated beds of marl, the total deposit is too small to ever become available for cement manufacture.

MARSHALL COUNTY.

REFERENCES.—

1859.—Richard Owen, Geol. Reconn. of Ind., p. 209.

1885.—W. H. Thompson, Fifteenth Ann. Rep. Dep. Geol. & Nat. Hist. of Ind., p. 177.

1899.—Frank Leverett, Water Supply and Irrigation Papers, U. S. Geol. Surv., No. 21, p. 37.

Marshall County lies south of St. Joseph in the second tier south of the Michigan-Indiana line. It is bounded on the east by Elkhart and Kosciusko; on the south by Fulton and on the west by Starke and St. Joseph counties. In outline it is almost square and contains an area of 440 square miles. The Tippecanoe River forms a loop in the extreme southeast corner, entering three miles north and leaving three and a half miles west of the corner. Yellow River is formed by the junction of its three main branches in the northeastern part of the county and, flowing in a southwesterly direction, leaves the western edge on the line between West and Union townships. Yellow Bank and Pine Creek, tributaries of the Kankakee, drain the northwestern fourth of the county.

Railway facilities are ample, three great trunk lines, viz., the Baltimore & Ohio, Pittsburgh, Ft. Wayne & Chicago and "Nickel Plate," crossing the county from east to west, while the Logansport Division of the Vandalia crosses from north to south, and the Lake Erie & Western from southeast to northwest. Three of these lines converge at Plymouth, the county seat, and furnish an excellent outlet in all directions. The following is the altitude in feet above sea level of the principal stations along these railways: Argos, 824; Bourbon, 836; Bremen, 813; Burr Oak, 782; Culver, 751; Donelson, 783; Harris, 838; Hibbard, 783; Inwood, 839; La Paz Junction, 851; Plymouth, 790; Tee Garden, 768; Tippecanoe, 783; Twin Lakes, 807; Tyner, 790.

The entire county is covered with glacial debris the bottom of which has been reached only at Plymouth, where stratified rock was found at a depth of 242 feet. The prominent Maxinkuckee moraine passes through the western range of townships from south to north. In the southwestern part of the county it forms a series of morainic knolls and ridges about Lake Maxinkuckee which add much to the attractiveness of the scenery about the lake. Outside of the area covered by this moraine the surface of the county is, for the most part, a gently undulating plain, broken only by shallow ravines and valleys formed by the erosion of the streams above mentioned.

The lakes of the county are few in number, but two—Maxinkuckee and Lake of the Woods—being large enough to attract tourists and sportsmen to their bounds. Of these Lake Maxinkuckee is fully described below. It ranks among the larger and is one of the most picturesque and best known of all the morainic lakes of northern Indiana. But two workable deposits of marl occur in the county, both being in Union Township in the southwestern corner.

LAKE OF THE WOODS.

Not a Workable Deposit.

This lake lies two miles south of the Baltimore & Ohio Railway, on the line between the civil townships of German and North. It is about four miles southwest of Bremen and the same distance southeast of La Paz, and occupies parts of sections 1 and 12 (34 north, 2 east) and sections 6 and 7 (34 north, 3 east).

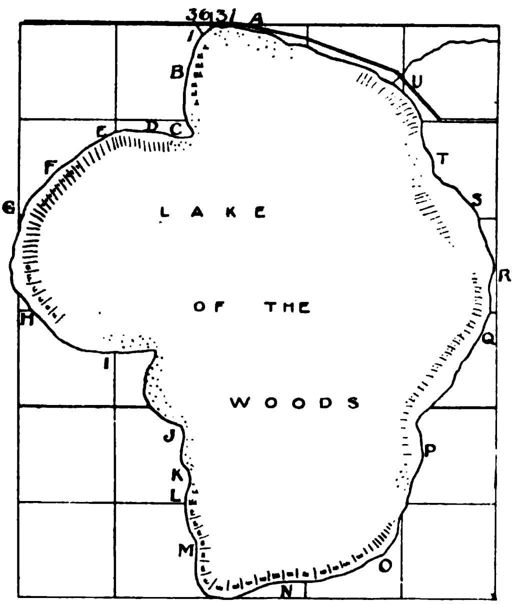

Fig. 57. Map of Lake of the Woods, Marshall County, Ind.

The length of the lake from north to south is one and one-half miles and its extreme breadth about one and one-fourth miles. In shape it is oval with a fairly regular outline except on the west, where a broad bay increases the width half a mile. In most places the area of shallow water is rather broad, the shores in general sloping back gently from the water's edge.

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Marl.—Marl is found at most points around the lake, but is generally quite shallow. Starting with a sandy bottom at (A) tests out to 10 feet of water showed only muck which, at (B), was from three to seven feet thick. Around the point at (C) the bottom is hard. Between (D) and (H) some marl is struck at all points, running in thickness from one to seven feet. At (F) and (H) from three to five feet of muck overlies the marl.

From (I) to (K) the bottom is sandy, becoming toward (K) a marly sand. At (L) eight feet of muck was found. Toward (M) this becomes marly, while near (N) a foot of marl is found beneath eight feet of muck. At (O) the thickest marl was found, there being nine feet beneath seven feet of water. From (P) to (R) the marl is from one to two feet thick overlain by a few inches of sand. Over a considerable area near (S) the marl is only a few inches deep. At (T) the bottom is sandy, while at (U) a few feet of marl are found.

While there may be a large deposit of marl under the deeper water of the lake, that beneath shallow water is not sufficient to justify further consideration.

LAKE MAXINKUCKEE.

By Dr. J. T. Scovell.

Large Workable Deposit, Partly Under Deep Water.

Lake Maxinkuckee occupies parts of sections 15, 16, 21, 22, 27, 28 and 34 (32 north, 1 east). The lake is a little more than two and one-half miles long from north to south and about one and a half miles wide, having an area of nearly 1,900 acres. The surface of the lake is about 734 feet above tide. It is 150 feet above Lake Michigan, but 130 feet below the summit of the divide between Lake Michigan and the Wabash River. The lake is 15 feet above the Tippecanoe River five miles south, and about 75 feet above English Lake, 20 miles west. These elevations show that it is on a slope that descends gently toward the south and west. The lake is near the southwestern angle of the Saginaw moraine and the country surrounding it is quite varied. There are hills and valleys, broad undulating plateaus, wet marshes and boggy swamps. The soils are sand, gravel, boulder clay and swamp muck. There are more hills and clay and boulders on the east, more sand and gravel, more marshes and swamps on the west. On the east the surface rises somewhat abruptly to a general level of 75 or 80 feet above the lake, some hills reaching an elevation of about 140 feet. On the west there is a

narrow divide 25 to 30 feet above the lake, then low land and swamp. The confused mingling of sand, gravel, clay and boulders, the irregular hills and the numerous kettle holes, show plainly that the surface features about the lake are of glacial origin.

Wells drilled from 75 to 150 feet through sand, gravel and clay without reaching bed rock indicate that the lake bed is wholly composed of morainic materials. In fact, it seems to occupy a cluster of kettle holes, one long and deep surrounded by several of lesser size and depth. In outline the lake is regular, Long Point on the west forming the only acute angle in its shore line.

The region drained into the lake is quite limited, being scarcely more than three times its area. On the north, west and south the divide is not, on the average, more than 40 rods from the lake. On the east and northeast, in some places, the divide is a mile and a half distant. On the east the drainage area has been much extended by ditches which reach into undrained areas. The largest inlet flows into the northeastern part of the lake, sometimes called Culver Bay. The main stream rises about a mile and a half east and flows northwesterly, westerly and southwesterly into the lake. A large branch of this stream rises about the same distance north of the lake and flowing southerly through a broad shallow valley joins the main stream near the lake. The middle course of the main stream is through a deep narrow valley and is largely made up by springs. The current in the main stream is quite strong, while the branch is a sluggish stream. Along the lower course of this inlet there are perhaps 100 acres of low ground, sometimes boggy, sometimes marshy, but generally the hard sand is at or near the surface. Through this tract the stream flows in an artificial channel. This low area seems to be rich in small springs. A second inlet, sometimes called the Norris Inlet, flows into the southeastern angle of the lake. It rises about a mile and a half east and flows westerly through a broad valley into the lake. Much of its upper course is through an artificial channel. The lower course is through a marsh about 80 rods wide and half a mile long. In this the current is very sluggish and so obstructed by vegetation that in summer it is difficult to follow the stream. This stream is fed by springs, but they are not as abundant as along the one flowing into Culver Bay. The southeast inlet is generally considered the main inlet, but the one from the northeast carries the most water. A third inlet, Aubeenaubee Creek, comes into the lake from the east. It rises about one mile east of the lake and flowing westerly and northwesterly, breaks through the low bluff, entering the lake about midway between the other two streams.

It is a small, sluggish stream, and much of its course is through low, marshy or swampy ground. The greater part of its upper course is through an artificial channel. Like the others, this stream is largely fed by springs. The low ground, some 200 acres in area, through which it flows, is separated from the lake by a narrow ridge. It seems possible that it might formerly have been a shallow lake or pond, whose outlet gradually cut down its bed till the pond was drained nearly to the level of the main lake. The marsh and swamp vegetation advancing as the water was drained away at length took possession of the whole area. Besides these larger streams there are three other small streams from the east and two from the south, but none rise more than half a mile from the lake. Those from the east are largely fed by springs and flow during the year, but those from the south are generally dry during much of the summer. On the extreme northwest of the lake there are 30 or 40 acres of marsh land. Around this area are many springs that contribute to the waters of the lake.

The outlet is a sluggish stream which flows from the west side of the lake southerly into the Tippecanoe River. The valley of the outlet is about 80 rods wide and consists mainly of marsh land. As it leaves the lake the outlet is about 16 feet wide and 20 inches deep. About 80 rods from its exit the outlet expands into a shallow pond or lake having an area of about 60 acres and a depth of from three to 12 feet. This is commonly known as Lost Lake, but is sometimes called Little Maxinkuckee or Little Lake. Below Lost Lake there is perhaps 80 rods of definite stream, and then a half mile or so of marshy pond and then a definite stream again with low marshy banks. During the summer the stream in many places is clogged by vegetation so that the current is almost imperceptible. The marshes along the east and southeast inlets, the one along the outlet and the one on the northwest of the lake all seem to be underlain by a bed of hard sand, the muck or black mud varying from one to 20 feet in depth. The lake shore even along these marshes is generally hard sand. There is a little black mud near the outlet and some near the southeast inlet, but fully 99/100 of the beach is hard sand or gravel.

SPRINGS AND FLOWING WELLS.—*"The springs which feed Maxinkuckee are very abundant, not only from the shores, but they may be seen in the clear water at a depth of 10 feet gushing up from the bottom, and from the deepest parts of the lake rise columns of cold water, chilling the bather like an ice bath. These springs suggested the probability of obtaining successful flowing wells, and along the eastern and northern borders of the lake a number of such wells

*This section is taken verbatim from the reports of W. H. Thompson and Frank Leverett, locs. cit.—W. S. B.

have been obtained which rise to a height of 12 to 30 feet above the lake surface. The water from these wells is very clear and cold, and more or less ferruginous, a few of the wells being so highly impregnated with iron as to render the water slightly unpleasant to the taste until one gets used to it. Most of the water, however, is excellent at the first taste, and all of it is perfectly wholesome in use. The first well driven was only 13 feet in depth. Several have a depth of but 20 or 25 feet. Others are put down to a depth of 50 to 75 feet. One well has a depth of 160 feet, and one reached a depth of 203 feet. There appear to be several water horizons, but the head is no greater from the deep wells than from the shallow ones, and the upper horizon is as strong as any.

"The deepest of these flowing wells it at the residence of D. W. Morman. At the time of the writer's visit the water scarcely reached the surface, 20 feet above the level of the lake. Of the 203 feet penetrated, fully 90 per cent. is thought to have been till, the sand beds being but a few feet in thickness.

"Two wells on the northeast shore have a head 31 feet above the surface of the lake. These wells are each 72 feet in depth and have the following section:

Soil and yellow clay	8 feet.
Sand	14 feet.
Blue clay	38 feet.
Sand and gravel	12 feet.
Total	72 feet.

"A short distance east of these wells the head in a well 50 feet in depth is but 19 feet above the lake. The well at the Peru Clubhouse, on the east side of the lake, was bored to a depth of 160 feet and obtained only a weak flow. At the Indianapolis Clubhouse a good flow was obtained at only 27 feet. At the Highland House a well 33 feet in depth entered water-bearing sand at a depth of 13 feet. Near the Highland House D. W. Morman, of Indianapolis, has several wells. Four of them, averaging about 22 feet in depth, are estimated to have a combined discharge of 15 barrels per minute. These wells feed a ram which supplies the grounds with water. Mr. Morman also has a deeper well, with the following section, in which the flow was obtained from the sand above the blue clay:

Yellow clay	11 feet.
Sand	25 feet.
Blue clay	62 feet.
Total	98 feet."

Surface Levels of the Lake.—The level of the lake varies but little, probably not more than two or three feet. Records made by the Vandalia Railway people show the elevation of the ground at Culver Station to be 751 feet above tide. The surface of the lake is about 734 feet. Between October 18, 1895, and December 7, 1898, the variations were from 733.30 feet up to 735.17 feet, a total of only 1.87 feet. I could get no account of very high water, but the lake is said to have been very low in the autumn of 1871, when for nearly two months there was no water flowing in the outlet. When the level of the water in the lake is 734 feet there is about 20 inches of water in the outlet. During the low water of 1871 the level of the lake must have been down to or below 732 feet. This would indicate an extreme variation of only a little more than three feet in the level of the lake. During the greater part of the year the outflow about equals the inflow, so there is but little change of level, but during a dry summer the inflow is greatly lessened and the rapid evaporation quickly lowers the water in the lake. The flow of water in the outlet is so sluggish that the level of the lake is much affected by rains. Two days of heavy rain in August, 1895, raised the level of the lake about six inches. A rain beginning during the night of February 24, 1899, and continuing through the next day raised the level about five inches. During the high water the flow in the outlet is, of course, more vigorous, but it takes weeks and sometimes months to carry off the surplus water from a rain of two or three days.

The physical conditions about Lake Maxinkuckee seem quite permanent. The lake can not be drained much below 732 feet nor can it be raised much above 735 feet. These changes could only affect the character of some 200 acres of marsh land. When the level is about 735 feet much of the marsh along the southeast inlet and along the outlet is flooded so that perhaps from 75 to 100 acres of marsh grass can not be cut with a mower. When the level is 733 or less this marsh land is comparatively dry and teams can work over most of it without difficulty.

Topography of the Lake Bed.—In studying the bed of the lake over 1,200 soundings were made. They were taken along 23 different lines, which were located with reference to fixed lines and points in the U. S. survey. They were made at intervals of 10 or 15 oar strokes. The length of an oar stroke of course varied, but for a given line they would be practically the same. Knowing the length of the line and the number of soundings the average distance between soundings was easily worked out, and the locations may be regarded as fairly accurate. While tracing out the outlines of bars

and deep holes several hundred soundings were made between the lines mentioned. The soundings were made during the summers of 1897-1898 and 1899, at intervals as the wind and other circumstances were favorable. In sounding along the established lines we used piano wire and a wheel of known circumference. In work on the bars a sounding pole 13 feet in length was used. Much of the lake bed is covered with a very fine mud which made it difficult to tell just where the water stopped and the bed began. But in spite of this and other difficulties, the accompanying map gives a fairly correct idea of the topography of the lake bed. On the east and west line, through the center of sections 21 and 22, just east of the center of the lake we found water 85 to 89 feet deep. We heard about much deeper water but could not find it. There is only a small area of this deepest water, about 18 or 20 acres, but it is just north of the center of some 300 acres of deep water, water from 40 to 80 feet in depth. This body of deep water is near the geographical center of the lake and includes nearly all the water that is over 40 feet in depth. In this central mass toward the southwest there is a detached body of water over 60 feet deep, and there are two similar bodies of water over 50 feet deep, one north and the other south. In the southern part of the lake there is a small area of 40-foot water and there are two small areas of 40-foot water in the northwestern part of the lake. Fully one-half the area of the lake is shallow water, 10 feet or less in depth. These areas of shallow and deep water are very irregular in outline, and the connecting slopes are sometimes gradual, but often very abrupt, so that the surface of the lake bed is quite as varied and irregular as the surface of the surrounding country.

The body of deep water, nearly three times longer than wide, suggests the idea that an old preglacial drainage channel was possibly the origin of the lake bed. Kettle holes are numerous on both sides of the lake, forming prominent features of the moraine, and they seem to be the rational explanation of the lake bed. The original bed may have been a number of kettle holes, and the surface was doubtless sand and clay and gravel. But changes have occurred. The shallow parts have been modified by waves and currents and floating ice. The remains of the plants and animals living in the lake have contributed materials to the lake bed and so have the forests and other vegetation around the lake.

The distribution of soils and vegetation in Lake Maxinkuckee is very interesting. Along the shore near the marshes, bogs and inlets there is some soil and considerable vegetation. Where the banks are

abrupt and gravelly or clayey, soil and vegetation are both scanty. Almost everywhere from a depth of one or two feet out to a depth of six or eight feet the same conditions prevail. On the east large areas in this zone are almost devoid of vegetation, but on the north, west and south the bed of the lake in this zone is well covered with a stunted growth of lime-encrusted chara, with occasional plants of *Potamogeton natans*, *P. lucens*, and *Scirpus lacustris*. From six to eight feet to 20 or 25 feet the white mud or marl forms a soil, and 12 to 15 different species of plants abound, generally forming a rank growth. The zone of shallow water is swept clean of all fine material, whether mud or marl. This seems to have been done by undertow currents caused principally by the winds. Westerly winds are more common and are generally stronger than other winds, and on the east, where such winds would make the stronger current, we find the hard gravel bed reaching out into much deeper water than on the other sides of the lake.

During the summer of 1899, from June 27th to September 6th, inclusive, I noted the direction of the wind 223 times, morning, noon and night, as follows: Easterly 90, westerly 31, northerly 34, southerly 47, calm 21. During the summer months the easterly winds prevail, but during the year the westerly winds prevail and are in general stronger than the winds from the other quarters. The westerly winds probably account for the broader, barren zone on the east, while the winds from other quarters cause currents over lesser areas on the other sides of the lake. It seems possible that differences of temperature between the shallow and deep water, while seldom more than two or three degrees, might also cause currents toward the deeper water strong enough to move fine materials. On July 29th, 1899, when the lake was quiet, I found a bottom temperature of 77° F. in shallow water and 79° in water seven feet deep. On the 30th it was 76° in the shallow water and 79° in the deeper water. On September 1st, 1899, it was 77° in shallow water and 79½° in the deeper water. This difference of temperature would not cause a very vigorous current, but it might do something. The difference in temperature between the surface and bottom of the deeper portions of the lake is much greater, the bottom temperature in summer being 47° to 50° F., while the surface gets as warm as 77° to 80°.

A few of the temperature observations taken in different months on the air and water are as follows:

	On West Side Lake.	6 A. M. (Deg. Fahr.)	2 P. M. (Deg. Fahr.)	8 P. M. (Deg. Fahr.)
July 28, 1899	Air	74	83	81
July 28, 1899	Water, 18 inches	78	84	82
July 29, 1899	Air	77	81	72
July 29, 1899	Water, shallow	77	87	80
July 30, 1899	Air	62	75	73
July 30, 1899	Water, shallow	74	82	78
July 31, 1899	Air	69	77	75
July 31, 1899	Water, shallow	75	84	80
August 1, 1899	Air	68	83	77
August 1, 1899	Water, shallow	76	82	79
August 5, 1899	Air	70	76	74
August 5, 1899	Water, shallow	79	82	80
August 6, 1899	Air	71	80	76
August 6, 1899	Water, shallow	75	80	78

	Ice. (Inches.)	Air. (Deg. Fahr.)	Water. Surface. (Deg. Fahr.)	Water. Bottom. (Deg. Fahr.)
November 24, 1898	....	20	40	....
November 26, 1898	....	5	35	....
November 27, 1898	....	20	34	....
December 7, 1898	....	16	32	....
December 8, 1898	....	5	32	....
December 9, 1898	3	10	32	....
December 14, 1898	7½	5	32	34
January 4, 1899	8	0	32	34
January 8, 1899	6	30	33	34
January 29, 1899	10	13	32	34½
January 30, 1899	10½	0	32	33
January 31, 1899	11	9	32	34
February 1, 1899	11½	8	32	35
February 2, 1899	12	10	32	34
February 10, 1899	16	20	33	36
February 13, 1899	18	8	32	35
February 15, 1899	18	19	32	34
February 27, 1899	15	16	36	39
March 11, 1899	10	50	33	38

On March 11th and 12th the ice melted rapidly, and on the 13th was broken up by a strong west wind and gradually piled up on the east side of the lake. There was some snow and cold weather, but the ice was all out on the 25th. The thickest ice of which I could hear was about 28 inches in 1884.

As has been noted, the winter ice forms to a thickness of from 15 to 25 inches. As the ice expands it crushes against the banks with great force. Where the shores are low the ice often pushes great quantities of sand and other materials up into ridges, sometimes two or three feet high. These ridges or ice beaches are generally washed away by the high water common in spring, but sometimes they remain, making a distinct and somewhat peculiar plant

region. Along the steep banks, the boulders that have fallen to the beach during the summer are crowded against the bank by the ice, making in some places quite extensive stone walls.

FLORA OF THE LAKE.—With such a variety of soils as occur in and about Lake Maxinkuckee, a varied flora may be expected. In the waters of the lake there are great quantities of microscopic life which, in its totality, is called *plankton*. Of the microscopic plants *Protococcus, Rivularia, Oscillaria,* diatoms, desmids and others are common everywhere in the open lake, but were most abundant among the higher vegetation along the shores. Occasionally *Rivularia* would occur in such quantities as to be conspicuous to the naked eye. *Spirogyra, Vaucheria, Œlogonium, Hydrodiction, Stigeoclonium, Nostoc, Cladophera, Zygnema, Chetophora* and others, often occurred in masses in the shallow waters. Besides these lower forms, the following strictly aquatic members of the higher plants occur in the waters of either Lake Maxinkuckee or Lost Lake, or both. The nomenclature of the Phanerogams is that of Britton & Brown's "Illustrated Flora of the Northern United States."

NITELLA SP. ?

A tall slender plant; was abundant between 18 and 22 feet, ranging from 12 to 25 feet. In water from 20 to 25 feet deep we seldom found anything besides this Nitella.

NITELLA SP. ?

A small delicate plant found in shallow water, common in the marshes and in the lake out to a depth of two feet.

CHARA SP. ?

A slender, rank growing plant, quite free from lime; was abundant between 10 and 14 feet, ranging from eight to 24 feet. In some localities this chara was the only plant found between 10 and 14 feet.

CHARA SP. ?

A stout plant, seldom more than eight inches high, was thickly coated with lime. It was most abundant at a depth of from six to eight feet, often forming a thick mat of vegetation to the exclusion of other plants.

CHARA SP. ?

Much smaller than the above mentioned, quite abundant in shallow water, often the only vegetation. It was usually thickly coated with lime.

There are doubtless other species of Chara and Nitella about the lake, but the ones mentioned are the most abundant.

POTAMOGETON NATANS L. Common Floating Pondweed.

This plant was more common in the southwestern portion of the lake, growing in water from four to six feet deep.

POTAMOGETON AMPLIFOLIUS Tuckerm. Large-leaved Pondweed.

This plant was abundant in water from five to eight feet deep but ranged from two to 24 feet. On the Sugar Loaf Bar it was abundant and rank in depths from nine to 24 feet.

POTAMOGETON LONCHITES Tuckerm. Long-leaved Pondweed.

This pondweed was common everywhere in shallow water. A cluster of rank potamogetons growing in eight to ten-foot water on Weed Patch Bar I called *lonchites*, but I do not feel quite sure that I was correct.

POTAMOGETON HETEROPHYLLUS Schreb. Various-leaved Pondweed.

This plant was quite common out to a depth of four feet.

POTAMOGETON LUCENS L. Shining Pondweed.

This plant, sometimes called Perchweed, was widely distributed growing most commonly in water from six to eight feet deep.

POTAMOGETON PRELONGUS Wulf. White-stemmed Pondweed.

Not very common; growing in water from eight to 10 feet deep.

POTAMOGETON PERFOLIATUS L. Clasping-leaved Pondweed.

Not common but quite abundant in a few localities in the south part of the lake. More common in water from eight to 12 feet deep.

POTAMOGETON ZOSTERÆFOLIUS Schurm. Eel-grass.

Quite common. More abundant between 10 and 16 feet, but ranging from two to 26 feet.

POTAMOGETON FRIESII Ruprecht. Fries' Pondweed.

Widely distributed. More abundant between 12 and 16 feet, but ranging from eight to 25 feet.

POTAMOGETON PUSILLUS L. Small Pondweed.

More common in the southeastern portion of the lake in deep water, ranging from 10 to 24 feet.

POTAMOGETON PECTINATUS L. Fennel-leaved Pondweed.

Forming thick masses, excluding other vegetation, in water 10 to 16 feet deep; also in shallow water. It often stands at the head of a steep slope.

POTAMOGETON ROBBINSII Oakes Robbins' Pondweed.

Very common in the shallow waters of the Little Lake, but in the large lake more common in water from 10 to 18 feet deep, ranging from two to 24 feet.

NAIAS FLEXILIS (Willd.) Rost and Schmidt. Slender Naias.

Very abundant, ranging from one to 24 feet. Most common in the northeastern part of the lake.

NAIAS FLEXILIS ROBUSTA Morong.

This plant, while not common, was found in several localities.

SAGITTARIA GRAMINEA Michx. Grass leaved Arrow-head.

In the shallow water of the Little Lake.

PHILOTRIA CANADENSIS (Michx.) Britton. Water-weed.

Very abundant in a few localities in shallow water, as near the head of the outlet. It is widely distributed in deep water, ranging from one to 22 feet.

VALLISNERIA SPIRALIS L. Eel-grass; Tape-grass.

Said to be the wild-celery of Chesapeake Bay. The plants bearing pistillate flowers grow in shallow water. I saw none deeper than two or three feet. The male plant was most abundant in water from eight to 18 feet. We found it as deep as 24 feet. The pistillate flower is carried to the surface of the water by a long threadlike scape. After fertilization the scape forms a spiral of several coils drawing the ovary several inches under water, where the seeds ripen. The staminate flower has a short peduncle. When the pollen is mature, the flower separates from the plant and rises to the surface. The pollen, escaping from the anther, floats away to the pistillate flowers. The buds or stolons formed in the fall, on the male plant, are highly prized by mud hens and ducks as food. They will dive 10 or 15 feet for them. The shores are often thickly covered with the leaves they break off while getting these dainty bits of food.

ELEOCHARIS INTERSTINCTA (Vahl.) R. and S. Knotted Spike-rush.

In shallow water in both lakes, often forming large patches.

ELEOCHARIS MUTATA (L.) R and S. Quadrangular Spike-rush.

Abundant in shallow water near the mouth of the southeast inlet.

ELEOCHARIS PALUSTRIS (L) R. and S. Creeping Spike-rush.

Found along the southern shore of Lake Maxinkuckee.

SCIRPUS AMERICANUS Pers. Chair-makers' Rush.

Common in the shallow water of both lakes.

Scirpus lacustris L. Great Bulrush.

Common in the western and southern portions of the lake out to a depth of seven or eight feet. Specimens from 10 to 13 feet long often occur.

Spirodela polyrhiza (L.) Schleid. Greater Duckweed.

Common in quiet waters about the lake shores.

Lemna trisulca L. Ivy-leaved Duckweed.

Common in the outlet and in the southeast inlet.

Lemna minor L. Lesser Duckweed.

Often found with *Spirodela.*

Wolffia columbiana Karst.

In the southeast inlet and in the outlet.

Eriocaulon septangulare With. Seven angled Pipewort.

In Lake Maxinkuckee, but not common.

Brasenia purpurea (Michx.) Casp. Water Shield.

Very abundant in the outlet, only occasionally found in the lake.

Nymphæa advena Soland. Large Yellow Pond Lily.

Common.

Castalia odorata (Dryand) Wood and Wood. White Water Lily; Pond Lily.

Abundant in the outlet and in the Little Lake. Only occasionally found in the larger lake.

Ceratophyllum demersum L. Hornwort.

Common everywhere to a depth of 24 feet. Abundant in shallow water and quite plentiful between 14 and 20 feet.

Batrachium trichophyllum (Chaix.) Bossch. Stiff White Water Crowfoot.

Abundant in the southeastern part of the Little Lake.

Roripa nasturtium (L.) Rusby. Water Cress.

Abundant in the northeast inlet and in other places.

Myriophyllum spicatum L. Spiked Water Millfoil

Abundant in the Little Lake and in the outlet. In water from two to eight feet deep.

Myriophyllum verticillatum L. Whorled Water Millfoil.

Found in both lakes; not deeper than 14 feet.

Utricularia purpurea Walt. Purple Bladderwort.

In outlet.

UTRICULARIA VULGARIS L. Greater Bladderwort.
In the outlet and Little Lake, and also in the northeast inlet.

UTRICULARIA INTERMEDIA Hayne. Flat-leaved Bladderwort.
In the outlet and Little Lake.

UTRICULARIA MINOR L. Lesser Bladderwort.
In the Little Lake and outlet.

UTRICULARIA GIBBA L. Humped Bladderwort.
In the outlet.

UTRICULARIA BIFLORA Lam. Two-flowered Bladderwort.
In the Little Lake.

BIDENS BECKII Torr. Water Marigold.
Found in both lakes. Not very abundant, but ranging from two to 20 feet in depth.

The two following are found in the mud along shore:

PELTANDRA VIRGINICA (L.) Kunth. Green Arrow-arum.
Found in shallow water of both lakes, often in the mud along shore.

PONTEDERIA CORDATA L. Pickerel-weed.
Common in shallow water of both lakes, often above water line along shore. Both of these plants, after fertilization, bend over, thrusting the ovary into the water or mud, where the seeds ripen.

On the marshes below the level of high water are found the following species and more than 60 others, largely sedges and grasses:

DRYOPTERIS THELYPTERIS (L.) A Gray. Marsh Shield Fern.
EQUISETUM FLUVIATILE L. Swamp Horsetail.
Found on Long Point, west of the lake.

TYPHA LATIFOLIA L. Broad-leaved Cat-tail.
Common in the marshes along the outlet and in the southeast inlet.

ALISMA PLANTAGO-AQUATICA L. Water Plantain.
Common along the margins of both lakes.

SAGITTARIA LATIFOLIA Willd. Broad-leaved Arrow-head.
Common.

DULICHIUM ARUNDINACEUM (L.) Britton.
ELEOCHARIS ACICULARIS (L.) R. and S. Needle Spike-rush.
More common along the east shore of the Little Lake.

SCIRPUS SMITHII A. Gray.
ACORUS CALAMUS L Sweet Flag; Calamus-root.
In the marsh just north of the Little Lake.

ALETRIS FARINOSA L. Star-grass; Colic Root.
In the marsh along the outlet.

IRIS VERSICOLOR L. Larger Blue Flag.
In the marshes along the outlet and the southeast inlet.

XYRIS FLEXUOSA Muhl. Slender Yellow-eyed Grass.
In the marsh north of the Little Lake and in swampy ground along the railroad just south of the main lake.

HABINARIA CILIARIS (L.) R. Br. Yellow Fringed Orchis.
Along the outlet.

HABENARIA LACERA (Michx.) R. Br. Ragged Orchis.
Along the outlet.

GYROSTACHYS CERNUA (L.) Kuntze. Nodding Ladies' Tresses.
In marshes west of the lake.

SAURURUS CERNUUS L. Lizards'-tail.
In woods along the northeast inlet.

JUNCUS EFFUSUS L. Common Rush; Bog Rush.
SALIX NIGRA Marsh. Black Willow.
Common.

SALIX DISCOLOR Muhl. Pussy Willow.
POLYGONUM SAGITTATUM L. Arrow-leaved Tear-thumb.
Common.

BETULA PUMILA L. Low Birch.
In swamps west of the lake.

SARRACENIA PURPUREA L. Pitcher-plant; Side-saddle Flower.
In swamps west of the lake.

DROSERA ROTUNDIFOLIA L. Round-leaved Sun-dew.
On the east side of Little Lake.

DECODON VERTICILLATUS (L.) Ell. Swamp Loosestrife.
Abundant at the mouth of the southeast inlet and about the Little Lake.

MIMULUS RINGENS L. Monkey flower.
Common along the edge of marshes.

LOBELIA SYPHALITICA L. Great Lobelia.
Common.

CUSCUTA CEPHALANTHI Engelm. Button-bush Dodder.
Common.

CEPHALANTHUS OCCIDENTALIS L. Button-bush; Globe-flower.
Common.

NYSSA SYLVATICA Marsh. Black or Sour Gum.
CAMPANULA APARINOIDES Pursh. Marsh Bell-flower.
Common in the marshes.

POLYGALA CRUCIATA L. Marsh Milkwort.
Along the outlet below the Little Lake.

SPIRÆA TOMENTOSA L. Steeple-bush.
Common.

Along the beach between low and high water we found:

PANICUM CRUS-GALLI L. Barn-yard Grass.
MUHLENBERGIA SYLVATICA Torr. Wood Muhlenbergia.
CYPERUS DIANDRUS Torr. Low Cyperus.
POLYGONUM PENNSYLVANICUM L.
IMPATIENS BIFLORA Walt. Spotted Touch-me-not.
Common along the shores of both the lakes.

HIPPURIS VULGARIS L. Mares'-tail; Joint-weed.
At the head of the outlet.

TEUCRIUM CANADENSE L. Wood Sage.
LYCOPUS VIRGINICUS L. Bugle-weed.
MENTHA PIPERITA L. Peppermint.
MENTHA SPICATA L. Spearmint.
Common.

MENTHA CANADENSIS L. Wild Mint.
XANTHIUM CANADENSE Mill. Hedgehog Burweed.
ECLIPTA ALBA (L.) Hassk. Eclipta.
In low ground south and west of the lake.

BIDENS CONNATA Muhl. Swamp Beggar-ticks.

Besides the above more than fifty others were found along the beach, making in all over two hundred plants in and about Lake Maxinkuckee growing below high water mark.

A LIST OF THE MOLLUSCA KNOWN TO OCCUR IN LAKE MAXINKUCKEE.

BY W. S. BLATCHLEY.

The writer has collected shells in and around Lake Maxinkuckee almost every summer since 1890. From his collection and from various notes on the species taken, the present list is prepared.

UNIVALVES.

1. **SUCCINEA AVARA Say.**
   Common on the stems and leaves of water lilies and beneath rubbish on the south and west shores.

2. **LIMNÆ STAGNALIS Linn.**
   A fragile and beautiful shell. Rather common among the reeds and water vegetation, especially in the vicinity of muck beds. More common in Lost Lake. Not mentioned by Call in his paper on Indiana Mollusca, but occurs in a number of the northern Indiana lakes.

3. **LIMNOPHYSA REFLEXA Say.**
   Common in both Lost and the main lakes, in the same situations as the last.

4. **LIMNOPHYSA PALUSTRIS Muller.**
   Much less common than *reflexa*, a half dozen specimens only having been taken.

5. **LIMNOPHYSA DESIDIOSA Say.**
   Abundant on the stems of water plants along the shores. One of the principal foods of snipe, and other shore-frequenting birds.

6. **PHYSA GYRINA Say.**
   Frequent on the lily pads and in piles of rubbish along shore.

7. **PHYSA HETEROSTROPHA Say.**
   Abundant in and about Lost Lake, and in the southeast corner of the main lake.

8. **PLANORBELLA CAMPANULATA Say.**
   Common in shallow water with sandy bottom; the prettiest of the discoidal group.

9. **HELISOMA TRIVOLVIS Say.**
   Abundant among the reeds and rushes all about the margin.

10. **Menetus exacutus Say.**

A minute and handsome species found sparingly on the under side of lily pads in different parts of the lake.

11. **Vivipara contectoides Binney.**

The most abundant univalve in the lake, unless it be *Goniobasis livescens*. After a wind storm in July and August, thousands of the dead shells of this species are washed up in windrows all along the shore. The living shells are often seen clinging to weeds in six to 10 feet of water.

12. **Vivipara intertexta Say.**

Much less common than *contectoides*. Reaches only about half the size. The specimens taken were very pretty, being of a uniform, rich wine color and highly polished.

13 **Campeloma subsolidum Anthony.**

This is the most common of the three species of the genus occurring in the lake. Numerous living specimens were taken in the seine in water two to five feet in depth, and dead ones are abundant along the shore after every summer storm.

14. **Campeloma decisum Say.**

Frequently taken while crawling along on the muddy or sandy bottom in shallow water.

15. **Campeloma rufum Haldeman.**

A half dozen or more specimens only were taken in company with the last two. Readily known by the pinkish color of the apex.

16. **Goniobasis livescens Menke.**

Abundant in shallow water areas, especially so where the bottom is sandy.

BIVALVES.

1. **Unio gibbosus Barnes.**

Quite frequent in one to five-foot water, especially along the west shore south of Long Point. This species, as represented in the lake, is smaller and the shells thinner than in the river forms of southern Indiana. The nacre of the lake forms is a deep purple, while in those from the larger streams it is usually white.

2. **Unio phaseolus Hildreth.**

This species is accredited to the fauna of the lake on the authority of Dr. R. E. Call, Proc. Ind. Acad. Sci., 1895, p. 145. It occurs rather commonly in the Wabash and White rivers, but in the lakes was noted only in Lake Tippecanoe.

3. Unio iris Lea.

One of the most common bivalves of the lake. "The species is found in all portions of the State, and is characterized by its beautiful nacre, the short, erect teeth, and the beautiful bands of green, together with the foldings on the beaks."—Call.

4. Unio subrostratus Say.

Not common in the main lake; more so in the muck and mud along the margins of Lost Lake, where a well marked variety, with a larger and broader beak, was taken. A specimen of this was sent, among others, to Mr. Chas. T. Simpson, of the Smithsonian Institute, for verification. In his reply he says: "The variety of *subrostratus* which you send is, so far as I know, confined to northern Indiana. It is quite remarkable, and would seem to be almost a distinct species. I have seen quite a number of specimens of it, and at first thought it a variety of *U. nasutus* (which occurs in northern Ohio, and probably in northern Indiana), but there seem to be intermediate forms connecting it with *U. subrostratus.* The variety will be described in a forthcoming monograph on the group."

5. Unio pressus Lea.

Several specimens were secured in low water along the south shore. It is common in some of the larger streams of the State, notably White river at Indianapolis.

6. Unio luteolus Lam.

This is also a very common shell in the main lake; but does not reach as large size there as in some of the lakes in northeastern Indiana.

7. Unio ventricosus Barnes.

Common, but smaller than in the streams farther south.

8. Unio circulus Lea.

Scarce; several specimens, of a depauperate form only, having been secured.

9. Unio coccineus Lea.

Not common. A few fine specimens were gotten along the south shore in 1894. In the streams of northern Indiana, especially in the Kankakee and Yellow rivers, it is abundant.

10 Unio rubiginosus Lea.

Common along the west and south shores on gravelly bottom.

11. UNIO PARVUS Barnes.

Not so common as the next which it closely resembles. Dr. Call has, however, given a table which enables one to readily separate the two, on page 517 of his paper on the Mollusca of Indiana.

12. UNIO GLANS Lea.

Quite common in the shallow water along the west and south shores. The smallest member of the family taken in the lake; the average size being about 1.2 x.7 inches.

13. MARGARITANA DELTOIDEA Lea.

This is also a small form, averaging about 1.5 x.8 inches. It is quite common in Lost Lake and along the south shore of the main lake.

14. MARGARITANA MARGINATA Say.

Quite common, especially on muddy or mucky bottom in three to five-foot water.

15. ANODONTA IMBECILLIS Say.

This very fragile and brilliantly colored form is frequent in both lakes; being found in the bays whose bottoms are of muck or mud; also in the outlet.

16. ANODONTA EDENTULA Say.

A common form on the sandy and gravelly bottom along the west and south shores.

17. ANODONTA SUBCYLINDRACEA Lea.

This is a handsome species of medium size; cylindrical in form, greenish in color, and with recurved and neatly folded beaks. It is quite common in the vicinity of muck beds and in the outlet. *A. ferussaciana* Lea is a synonym.

18. ANODONTA FOOTIANA Lea.

This is the largest and the most common *Anodonta* found in the lake. The average measurements are about 4x2 inches. Mature specimens are usually much eroded and the shells are reddish in color from the iron oxide in the mud which they inhabit.

THE FISHES OF LAKE MAXINKUCKEE.

BY W. S. BLATCHLEY.

Forty-five species of fishes are known to the writer to occur in Lake Maxinkuckee, or in the inlets and outlet of the lake. The following is a list of these, with brief notes on their comparative abundance, local habitat, etc. The nomenclature is that of Jordan & Evermann's "Fishes of North and Middle America:"

1. **Lepisosteus osseus (Linn.). Long-nosed Gar; Common Gar-pike.**
   Common in the lake, where it reaches a length of four feet. It and its congenor, the short-nosed gar, are rapacious pirates, ever preying upon the young and weaker members of the higher orders of fishes.

2. **Lepisosteus platostomus Raf. Short-nosed Gar.**
   Much less common in Lake Maxinkuckee than the preceding, but in Bass Lake, 12 miles west, it is abundant, and the only one there known.

3. **Amia calva Linn. Mudfish; Dogfish.**
   Common; especially so in Lost Lake. Reaches a weight of 10 pounds or more. Its food is also made up largely of other fishes, and, therefore, it and the gar pikes should be destroyed at every opportunity.

4. **Amieurus natalis (Le S.). Yellow Cat.**
   Not as common as the next, except in Lost Lake. The largest catfish of these lakes, often reaching a weight of two pounds.

5. **Amieurus nebulosus (Le S.). Common Bullhead.**
   Taken only in Lost Lake, where it is not common; but probably occurs also in the large lake.

6. **Amieurus melas (Raf). Black Bullhead.**
   Frequent in Lake Maxinkuckee in the deeper waters off the mouths of the inlets.

7. **Schilbeodes gyrinus (Mitch.). Slender Mud Tom.**
   Scarce in the lake. More frequent in the northeast inlet. This is one of the small "stone catfishes," which have a poison gland near the base of the pectoral fin. When handled they use the spine of this fin in defense, and a wound from it is more painful than that of the sting of a bumble-bee.

8. **Catostomus nigricans** Le S. **Hog Sucker; Stone Roller.**
Scarce in the lake, but occurring in small numbers in the larger inlets. A curious spindle-form species; usually found hugging the bottom in clear, rippling water. Known to every boy who has ever wielded a snare, but seldom caught with a hook.

9. **Erimyzon sucetta oblongus** (Mitch.). **Chub Sucker; Sweet Sucker.**
Frequent in the mouths of the inlets and in mucky places along shore.

10. **Campostoma anomalum** (Raf.). **Stone roller; Stone-lugger.**
Common in the inlets, especially in Aubeenaubee Creek. The members of this genus are readily known from all other minnows by their having the air bladder surrounded by many convolutions of the long intestine. In the spring the males have the head and often the whole body covered with large rounded tubercles.

11. **Pimephales notatus** (Raf.). **Blunt-nosed Minnow.**
Very common in both lakes and inlets. One of the best minnows for bass fishing.

12. **Semotilus atromaculatus** (Mitch.). **Horned Dace; Creek Chub.**
Scarce in the lake; abundant in the inlets. The largest of our Indiana minnows, and excellent bass bait.

13 **Notropis heterodon** (Cope). **Variable-toothed Minnow**
In the lake only; not common.

14. **Notropis whipplii** (Girard) **Silver-fin.**
Next to *Pimephales notatus*, the most common minnow in the lake. The males, in the spring, have the fins and belly covered with a clear satin-white pigment, whence the common name. The head is then armed with numerous small tubercles.

15. **Notropis cornutus** (Mitch.) **Silver side; Shiner; Rot-gut.**
The most common minnow in the inlets; much less common in the lake. The males are more brightly colored and have the lower jaw and top of the head armed in the breeding season.

16. **Rhinichthys atronasus** (Mitch.). **Black-nosed Dace.**
Only in the inlets where it is scarce. One of the most handsome of our smaller minnows.

17. **Hybopsis kentuckiensis** (Raf.). **Horny-head; River Chub.**
Occurs in the lake only near the mouth of the inlets, where it is scarce. In the deeper pools toward the sources of the inlets it is more frequent. An excellent bait for the larger game fishes.

18. **Umbra limi (Kirt.). Mud Minnow.**
Scarce in the lake, where it is found only near the mouths of the inlets or at the bottom of water 14 to 25 feet deep, from which it was occasionally dredged by Dr. Scovell, being found entangled in the plant *Nitella flexilis* brought up from those depths. More common in the inlets, especially in Aubeenaubee Creek. "A locality which, with the water perfectly clear, will appear destitute of fish will perhaps yield a number of mudfish on stirring up the mud at the bottom and drawing a seine through it."—(Baird.)

19. **Lucius vermiculatus (Le S.). Little Pickerel.**
Frequent in the lake; more so in Lost Lake. Found about the weedy margins in shallow water.

20. **Lucius lucius (Linn.). Common Pike; Pickerel.**
Formerly quite common in the lake, but now scarce, but one or two being taken each season. Frequents for the most part the bayous, mouths of inlets and patches of weeds in eight to 16-foot water.

21. **Fundulus diaphanus menona (Jor. and Cope). Common Killifish.**
Abundant in the shallow water near shore.

22. **Fundulus dispar (Agassiz). Top Minnow.**
Less common than the preceding; smaller and more prettily colored.

23. **Eucalia inconstans (Kirt.). Brook Stickleback.**
This handsome and interesting little fish has been taken in Indiana only in streams in Wabash and Decatur counties, and in Lake Maxinkuckee. In the lake it is quite common among the masses of *Nitella flexilis* at the bottom of 15 to 24-foot water. In dredging Dr. Scovell often found four or five entangled in the masses of *Nitella* which were brought to the surface.

24. **Labidesthes sicculus (Cope). Brook Silverside; Skipjack.**
Abundant. Frequents for the most part, shoal water, though it often occurs in schools, swimming close to the surface of the deep water. Into these schools the bass and other game fish dart and create sad havoc. The prolonged beak-like jaws and the slender translucent body render it easily noticeable and distinguishable from all other fresh water fishes.

25. **Pomoxis annularis Raf. Crappie; Bachelor.**
This species is inserted on the authority of Dr. Scovell. It is much less common than the next, which it closely resembles.

26. **Pomoxis sparoides (Lacépède). Calico Bass; Grass Bass.**

Frequent about the weeds in 10 to 18-foot water, but much less common than in Bass Lake. Often confounded with the preceding species, the name "croppie" or "crappie" being given indiscriminately to both. This species and the blue-gill, *Lepomis pallidus*, are, more often than any of the other game fishes, thrown by the waves in a dying condition on the shore, especially in July and August. They then appear to be attacked by some sort of a fungus growth.

27. **Ambloplites rupestris (Raf.). Red-eye; Goggle eye.**

Common in the lake in water from eight to 30 feet in depth. Frequents the vicinity of the weed covered slopes on the bottom. An excellent pan fish, easily hooked but not very gamy. Specimens weighing a pound and a quarter have been taken.

28. **Chænobryttus gulosus (Cuv. and Val.). War-mouth; Indian Fish.**

Found sparingly in the lake in water from 10 to 40 feet in depth; more common in the outlet and in Lost Lake. Reaches a weight of three-quarters of a pound, and is a fine food fish.

29. **Apomotis cyanellus (Raf.). Blue-spotted Sunfish; Green Sunfish.**

Inserted on the authority of Drs. Evermann and Jenkins, who note it as "very common" in their "List of the Fishes of Lake Maxinkuckee."*

30. **Lepomis megalotis (Raf.). Long-eared Sunfish.**

Common in water from two to 10 or more feet in depth; nesting, as do several other of the smaller species of sunfish, among the rushes on the sandy bottom. This is one of the most brilliantly colored of our fresh water fishes. They are the lords and ladies of the respective pools wherein they abide. When they move other smaller fry clear the way. If a worm or a gnat, falling upon the surface, tempts them, it is theirs. A leaf falls near them and is seemingly unnoticed—a fly, and how quickly their dormant energy is put into motion. With a dart and a gulp the insect is swallowed and a new stage of waiting expectancy is ushered in.

31. **Lepomis pallidus (Mitch.). Blue-gill; Blue Sunfish.**

Rather common in the lake in waters from eight to 40 feet. Probably the most gamy of all the sunfishes and a most valuable food fish. Specimens 11 inches in length to the base of the caudal fin have been recorded from the lake.

* Proc. U. S. Nat. Mus., 1888, p. 54.

32. **Eupomotis euryorus (McKay). Broad-eared Sunfish.**
Scarce. A few specimens have been taken in 15 to 40-foot water. A handsome species reaching a length of eight inches.

33. **Eupomotis gibbosus (Linn.). Common Sunfish; Pumpkinseed.**
Common in the shallow waters of the lake and in pools in the inlets. One of the smaller sunfishes; ranking with *L. cyanellus* in size, and approaching *L. megalotis* in the brilliancy of its colors.

34. **Micropterus dolomieu Lacépède. Small-mouthed Black Bass.**
Probably less common than the next species, but in every sense as gamy. Occurs at all depths, but is more common about the weed covered slopes in 10 to 25-foot water. Reaches a weight of nearly five pounds.

35. **Micropterus salmoides (Lacépède). Large-mouthed Black Bass.**
This is the larger of the two black bass, and the one most sought by fishermen. Specimens weighing from four to six pounds are frequent and, according to Mr. A. J. Knapp, proprietor of the Arlington Hotel, one weighing eight pounds and 11 ounces was taken in the lake a few years ago. Mr. Knapp himself has taken three which weighed over seven and a half pounds each, and one that weighed eight pounds three ounces.

36. **Stizostedion vitreum (Mitch.). Wall-eyed Pike; Jack Salmon.**
Frequent in the deep waters only. Large specimens are caught from September 15th to November 1st in 60 to 80-foot water. At night they go near the shores to feed and are then sometimes taken by trolling. Specimens 10 inches long have also been taken by seining at night. Two taken October 28, 1900, by Mrs. Knapp, weighed together eight pounds nine ounces.

37. **Perca flavescens (Mitch.). Yellow Perch; Ringed Perch.**
Common in all water under 30 feet. This species, the bluegill and goggle-eye, are the fish most commonly caught by still fishing from boats. The perch in Lake Maxinkuckee are mostly of small size, seldom exceeding three-quarters of a pound in weight.

38. **Percina caprodes zebra (Agassiz). Log Perch; Manitou Darter.**
The largest and most common of the darters taken in the lake. Reaches a length of six inches.

39. **Hadropterus maxinkuckiensis Everm. The Maxinkuckee Darter.**

Described from a single specimen taken in Aubeenaubee Creek, a half mile east of the lake in 1899. No others known. Length 3.5 inches. Closely related to and probably a variety of *H. scieurus* (Swain), the latter occurring in numbers in Yellow River, 11 miles north, and in Tippecanoe River, at De Long, five miles south.

40. **Boleosoma nigrum (Raf.). Johnny Darter.**

Next to *P. caprodes*, the most common darter in the lake; found everywhere along the sandy shores in one to 15-foot water. "In the spring the males have the head jet-black, and this dark color often extends on the back part of the body so that the fish looks as if he had been taken by the tail and dipped into a bottle of ink. But with the end of the nuptial season this color disappears and the fish regains his normal strawy hue."—(Jordan.)

41. **Etheostoma iowæ Jor. and Meek. Iowa Darter.**

Common along the shores in company with the preceding species.

42. **Etheostoma aubeenaubei Evermann. Aubeenaubee Darter.**

Quite frequent in Aubeenaubee Creek, where the species, up to the present, has only been found. Evidently derived from and closely related to *Etheostoma iowæ;* more brightly colored than that species. Reaches a length of only two inches.

43. **Etheostoma cœruleum Storer. Blue Darter; Rainbow Darter; Soldier Fish.**

Common, especially in the inlets. Reaches a length of two and a half inches. In the spring the male is the most gorgeously arrayed of all the darters. Then the blackish bars of other seasons are changed to indigo blue, while the space between them assumes a hue of the brightest orange. The fins are broadly edged with blue and have the bases orange, or orange and scarlet, while the cheeks assume the blue and the breast becomes an orange. Clad in this suit he ventures forth on his mission of love, and if successful, as he almost always is, the two construct a nest of tiny stones in which the eggs of the mother fish are laid and watched over with jealous care by both parents until in time there issue forth sons destined some day to wear a coat of many colors, and "darters" to be attracted by those coats, as was their mother by the one their father wore.

44. **Bolichthys fusiformis (Girard). Spindle-shaped Darter.**
Scarce. Found along the sandy shores of the lake in company with the johnny, iowæ and rainbow darters.

45. **Microperca punctulata Putnam. Least Darter.**
Rather common in the outlet and in Lost Lake; much less common in Lake Maxinkuckee. Frequents shallow water along sandy and weedy shores. The smallest of our Indiana darters; the length when full grown being but one and one-half inches.

NOTES ON THE TURTLES AND BATRACHIANS OF LAKE MAXINKUCKEE.

By W. S. Blatchley.

TURTLES.

The following species of turtles have been noted in and about the lake, either by Dr. Scovell, Prof. O. P. Hay or the writer:

Aspidonectes spinifer (Le S.). Common Soft-shelled Turtle.
Common; strictly aquatic; seldom seen basking in the sun as do many of the hard-shelled forms. Feeds on small fish, shrimps, tadpoles, etc.

Chelydra serpentina (L.). Common Snapping Turtle.
Common; the largest turtle in the lake. Lives for the most part in the muck and mud along the margins. Feeds upon frogs, fish, crayfish, the young of the water fowl, etc.

Aromochelys odoratus Latreille. Musk Turtle; Stink-pot.
Frequent; reaches a length of five or six inches, though most specimens seen were smaller. Occurs in all parts of the lake, but more especially among the reeds and rushes near shore.

Malaclemmys geographicus (Le S.). Map Turtle
Common; reaches a length of 10 to 12 inches. Often noted basking on roots, logs, etc. Several of the largest ones which have come to my notice were on a narrow ledge or platform of the boat-house at Culver Park on July 5, 1900. After crawling up from the water they spread out their broadly webbed feet in the sun and at intervals raised their heads and gaped widely. They were in company with a number of lady turtles of smaller size, and occasionally a large map turtle would crowd against one of its smaller neighbors and push it off its perch into the water. Prof. Hay says of this species: "At Lake Maxinkuckee three persons caught about 30 specimens of this species in a few hours.

Without probably an exception they were found near the shores, where there were great numbers of water-breathing univalves. After a number had been kept for a few days in a tub there were found in it large numbers of the opercles of such mollusks; and in the intestines of one were the remains of a crayfish, some fish scales, and what appeared to be the cases of some kind of caddis worm. Its broad masticatory surfaces are well fitted for crushing the shells of mollusks."*

Chrysemys marginata (Agas.). Lady Turtle.

Very common; especially in shallow water among rushes and water lilies. Reaches a length of seven inches. Feeds upon small mollusks, shrimps, tadpoles, etc.

Clemmys guttatus (Schneider). Speckled Tortoise.

Scarce in the lake; frequent, especially in the spring, in the streams and ditches leading to it. Two specimens were picked up one morning at Lake Maxinkuckee in May, 1891, by members of the Indiana Academy of Science. One of our smallest and prettiest turtles.

Emys meleagris (Shaw). Blanding's Tortoise.

Scarce; more often seen in spring during the mating season. Dr. Hay saw one on the lake margin in May. Frequent at Bass Lake, 12 miles west.

Cistudo carolina (L.). Common Box Turtle.

One or more, taken on different occasions in the strip of woods between the main lake and Lost Lake. A strictly terrestrial species.

BATRACHIANS.

The following species of Batrachians have been taken in the lake or close to its margin:

Necturus maculatus Raf. Mud Puppy; Water Dog.

A single specimen was found by the writer beneath a chunk in shallow water, south of the Arlington Hotel, in August, 1896. Said by both Hay and Scovell to be quite common. Is perfectly harmless, though almost universally believed to be very venomous.

*Seventeenth Ann. Rep. Ind. Geol. and Nat. Hist. Surv., 1891, p. 576.

Amblystoma tigrinum (Green). **Tiger Salamander.**

Dr. Hay records the taking of this species in the vicinity of Lake Maxinkuckee. It is our largest salamander and is quite common in many parts of the State.

Amblystoma jeffersonianum laterale Hallowell. **Jefferson's Salamander.**

According to Dr. Hay* this variety of Jefferson's salamander was taken by him near the margin of the lake.

Chondrotus microstomus Cope. **Small-mouthed Salamander.**

Several were taken from beneath chunks close to the water's edge in the woods east of Lost Lake, in May, 1899.

Plethodon erythronotus (Green). **Red-backed Salamander.**

Found on a number of occasions beneath rubbish in the woods bordering the south shore of the main lake.

Plethodon glutinosus (Green). **Slimy Salamander.**

Three half-grown beneath oak chunks some distance from water, at the southwest side of Lost Lake. All these salamanders doubtless visit the water of the lakes during the breeding season.

Diemyctylus viridescens Raf. **Newt; Green Triton.**

This species was taken by Dr. Hay in the lake, according to his statement in the report already cited. It exists in two or three forms, the one called *viridescens* being always found in water. It is among the most beautiful of our native salamanders.

Bufo lentiginosus americanus Anthony. **American Toad.**

Common along the sandy shores of the lake from May to October.

Acris gryllus crepitans Le Conte. **Cricket Frog.**

Very common in the short grasses and rushes along the shallow water margins.

Chorophilus triseriatus (Weid.). **Swamp Tree Frog.**

Two specimens were taken from the leaves of button bush in a marshy tract in the woods on the south shore in July, 1900.

Hyla versicolor Le Conte. **Common Tree Frog.**

Common in the trees and bushes about both lakes.

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* Loc. cit., p. 481.

HYLA PICKERINGII Holb.

Two or three specimens of this pretty little tree frog have been taken on the stems of tall marsh grasses near the south-eastern corner of the lake.

RANA VIRESCENS Kalm. Leopard Frog.

Everywhere along the marshy and grassy margins.

RANA PALUSTRIS Le Conte. Swamp Frog.

In the State Normal School collection are two specimens that were taken at Lake Maxinkuckee.

RANA CLAMATA Daudin. Green Frog.

Much more common than the above; occurs most frequently in the inlets and about the springs and runs from flowing wells.

RANA CATESBIANA Shaw. Bull Frog.

Frequent; especially so in Lost Lake and in the mouth of the southeast inlet.

MARL.—As noted above, Lake Maxinkuckee seems to occupy a cluster of kettle holes, one long and deep surrounded by several lesser ones. The original bed of the lake appears to have been composed of sand and gravel with perhaps some boulder clay. Over the greater part of this original bed thick beds of mud and marl have been deposited. In general, on the north, west and south, out to a depth of five or six feet, the present bed of the lake is of hard sand or gravel. On the east the hard bottom extends out to a depth of seven or eight feet and in some places there is hard bottom even under water 10 or 12 feet deep. Near the head of the outlet and about the mouth of the southeast inlet there is some black mud and muck in the shallow water. On the north, west and south sides of the lake marl begins at a depth of six or seven feet, and everywhere, under water up to 10 feet in depth, we found from eight to 15 feet of marl. On the east the marl begins a little farther out, generally in eight or 10 feet of water, and the marl was abundant in 12-foot water. Almost everywhere along the bars or along the shore, except on the east, there is an abundance of marl at the 10-foot water line; the thickness of the bed at this line averaging more than eight feet. Investigations in more than 200 different localities, under water from eight to 25 feet deep, disclosed beds of marl. Sometimes the marl was covered by a thin layer of black mud, but in general marl alone makes the bed of the lake.

Opposite the gravel pit, about 80 rods northwest of the center of section 28, we found marl more than 18 feet thick under water five feet deep. This was the only locality in which a thick body of marl occurs under shallow water. Wherever the bottom of the marl was reached, it was found to be resting upon a bed of sand and gravel. Under water deeper than 20 to 25 feet the marl is quite dark. It seems to be composed largely of calcium carbonate, mingled with more or less decaying vegetable matter. The samples from these greater depths were, however, secured with a dredge and were from the top of the deposit. There is little doubt but that the deeper marl would be of greater purity. Everywhere in the lake under water from eight to 16 feet deep the marl is almost white in color.

To be more specific as to locations we will say that beds of marl more than eight feet in thickness cover the greater portion of each of the following tracts of land, to wit:

The southeast quarter of the southwest quarter of section 15.
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The marl in different parts of the lake seems to differ in color and consistency, but whether such variations mean any important difference only chemical analysis or practical tests can show. An analysis of a sample from a bar east of the Long Point bar, just south of the center of the northeast quarter of section 28, made by Dr. W. A. Noyes, is as follows:

Calcium carbonate ($CaCo_3$)	85.02
Magnesium carbonate ($MgCo_3$)	3.85
Ferric oxide (Fe_2O_3)	0.33
Alumina (Al_2O_3)	0.12
Calcium sulphate ($CaSo_4$)	0.17
Insoluble inorganic matter (silica, etc.)	5.67
Organic matter	3.21
Total	98.37

This sample was taken five feet below the surface of the marl under about eight feet of water. A second sample, taken from the shore bar just east of the ice houses, had the following composition:

Calcium carbonate ($CaCo_3$)	85.38
Magnesium carbonate ($MgCo_3$)	3.50
Ferric oxide (Fe_2O_3)	.33
Alumina (Al_2O_3)	.05
Calcium sulphate ($CaSo_4$)	.17
Insoluble inorganic matter (silica, etc.)	6.40
Organic matter	3.15
Total	98.98

It will be seen that the composition of this sample is very similar to that of the first one and either analysis may be taken as about the average of the better marl beds of the lake.

An analysis of a third sample from the surface of a marl bed in deeper water in front of the gravel pit resulted as follows:

Calcium carbonate ($CaCo_3$)	75.07
Magnesium carbonate ($MgCo_3$)	4.18
Ferric oxide (Fe_2O_3)	.51
Alumina (Al_2O_3)	.09
Calcium sulphate ($CaSo_4$)	.11
Insoluble inorganic matter (silica, etc.)	15.26
Organic matter	3.65
Total	98.87

This shows too high a percentage of magnesium carbonate and insoluble matter, for cement making. These impurities are probably much less in the marl at a greater depth from the surface of the bed.

ORIGIN OF THE MARL AND MUD.—The marl and the mud of Lake Maxinkuckee seem to be secondary deposits upon an original bed of sand and gravel. What were the sources of the marl, what of the black mud, and what determined their distribution or arrangement? The well water and some of the spring water entering the lake is hard, much harder than the lake water, which is usually designated as soft water. The water of the lake does not contain an excessive quantity of calcium carbonate, yet it appears to be the source of the calcium carbonates found in the bed of the lake.* Several different forms of life, common in the lake, separate calcic compounds from the water, changing them into compounds that are practically insoluble in the waters of the lake. Perhaps the form of life that is most efficient in this work of separating calcic carbonate from the lake water is a species of *Chara*. This is abundant in the bed of the lake from near the shore to a depth of 10 or 12 feet, especially on the north, west and south. It must cover nearly one-quarter of the entire bed of the lake. The stems are from two to 10 inches long, making a thick mat over the bed of the lake. This plant is everywhere covered with a thick coating of calcic carbonate which makes it very brittle. There are other species of *Chara,* one, of much ranker growth, being found in water from 10 to 18 feet deep, but it seldom shows an appreciable coating of lime. Besides the *Chara,* several Potamogetons, as ***P. amplifolius, P. zosteræfolius, P. robbinsii, P. friesii, P. lucens, P. lonchitis, P. natans*** and ***P. heterophyllus,*** are generally found with a thick coating of lime over their leaves. Other plants separate lime from the water, but in such small quantities that they need not be mentioned.

Besides these plants, all mollusks of the list above given do much toward bringing about a deposition of the calcic carbonate. In many places, especially on the north, west and south, the bed of the lake is thickly covered with the bivalve mollusks. On the east the bed is too stony and the water too rough for many shells. We often found live shells in water from 20 to 30 feet deep, but they were much more common in shallow water. The univalves are abundant on the vegetation down to a depth of 20 feet. Frequently a half bushel of *Nitella* and *Potamogetons,* dredged from a depth of 18 to 20 feet, would contain more than 100 univalves, mainly *Vivipara.*

The marl of Lake Maxinkuckee, then, seems to have had its origin in calcic carbonate, which was separated from the shallow water by

***When the lake was young, the amount of calcium carbonate in its waters was probably far in excess of what it is to-day, and the rate of its deposition was, without doubt, more rapid. See p. 36.—W. S. B.**

mollusks and different species of *Chara*. This material, with other substances, carried into deeper water, became the foundation of the marl beds and formed a soil in which grew other plants that could separate calcic carbonate from the water. These plants furnished food for several species of mollusks and crustacea whose shells contributed largely toward the growth of the marl beds.

It is impossible, from data at present available, to estimate with any degree of accuracy the quantity of carbonate of lime deposited each year. On some Potamogeton leaves I found a coating of lime about 1/100 of an inch in thickness. Many shells of the univalves were but little thicker; perhaps 1/100 of an inch representing the thickness of the lime. Other shells were much thicker, but the amount given would probably represent the average thickness of lime formed each year. Add to these sources the lime from the stems of *Chara* and *Nitella* and the lime contributed by the plankton, and it seems as if 1/100 of an inch would be a conservative estimate for the thickness of the layer of carbonate of lime deposited each year over certain areas in Lake Maxinkuckee. If we estimate the average thickness of these deposits to be 10 feet, the lake would be some 12,000 years old. While these estimates seem conservative for the present, it is quite probable that the waters of the lake formerly contained a larger percentage of lime than they do now and that the deposition was more rapid than now. This circumstance might reduce the estimate by one-third, making the lake about 8,000 years old. I could find no data from which to estimate the rate of deposition of the black mud.

Lost Lake is protected by hills and forests from the easterly winds, while those from the west are unobstructed. On the east there is a hard sand beach, and bivalve mollusks are abundant. On the other sides it is generally muddy and the water vegetation is abundant. We found some marl in this lake and some in the marshes along the outlet and the inlets, but the areas were small and the material was generally quite dark from a mixture of vegetable matters.

TWIN LAKES.

By Dr. J. T. Scovell.

Not a Workable Deposit.

A group of four small lakes near the center of the western third of Marshall County are known as "Twin Lakes." They are about eight miles north of Lake Maxinkuckee, and the Logansport Division of the Vandalia Railway runs between them. Holem Lake is about

three-quarters of a mile long from northeast to southwest, and has an average width of about 30 rods. The banks in general are steep, with a narrow marsh between them and the water. Cook Lake is just northwest of Holem Lake and separated from it by a narrow ridge of gravel perhaps 20 feet high and 200 to 300 feet wide. It is about a mile long and about 40 rods wide. In this lake, as in the others, there is generally a narrow marsh between it and a steep bank. Holem and Cook lakes are, for the most part, in the northwest quarter of section 24 and the northeast quarter of section 23 (33 north, 1 east).

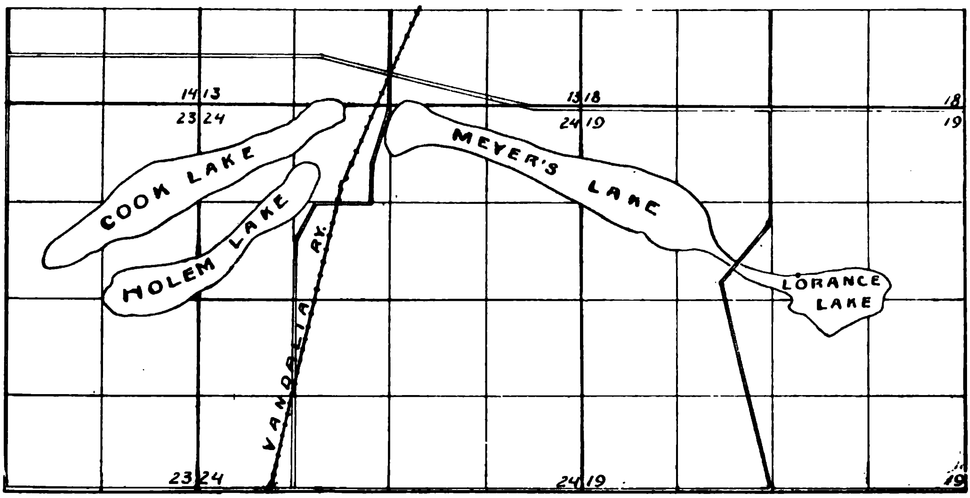

Fig. 59. Map of Twin Lakes, Marshall County, Ind.

Just east of the northeastern extremity of Holem Lake, across a low divide along which runs the branch of the Vandalia, is the head of Meyer's Lake. It is about one mile long and 40 rods wide, and extends from the northwest corner of the northeast quarter of section 24 (33 north, 1 east) southeasterly nearly to the center of section 19 (33 north, 2 east).

Extending southeasterly from Meyer's Lake is a narrow stream which, after a course of 40 or 50 rods, expands into a body of water known as Lorance Lake. This is separated from Meyer's Lake by the grade of a common wagon road. The lake has a length and breadth of about 80 rods each, and is about equally divided between the northeast and southeast quarters of section 19 (33 north, 2 east). Holem, Meyer's and Lorance lakes occupy what seems to be a portion

of an old drainage channel. The banks of the valley are generally steep and are, for the most part, composed of clay with some sand and gravel. The forest trees about the lakes are mainly oaks. In the water there was *Chara, Myriophyllum, Ceratophyllum, Potamogeton,* pickerel weed, pond lilies, bulrushes, and other vegetation quite similar to that in Lost Lake west of Maxinkuckee. Almost the whole shore line of each lake is marshy and muddy, there being only a few bits of hard sand beach. The lakes are comparatively shallow, 15 to 20 feet, and the area drained into them is very limited. In its widest place the valley is scarcely one-half mile wide. Two small streams flowing into Meyer's Lake were the only inlets I saw. From the southwestern extremity of Holem Lake an outlet flows into Cook Lake and from the southwestern extremity of Cook Lake an outlet flows southwesterly into Yellow River. Meyer's and Lorance lakes drain southeasterly, but finally reach Yellow River.

MARL.—All bores in Holem Lake pierced only a fine grayish to black mud over 12 feet deep. There was in general a thin layer of black mud, then a whiter marl-like mud that contained many fragments of shells. The water was nowhere more than 12 feet in depth. In Cook Lake 10 tests were made. In eight of these soft mud over 12 feet in thickness was found. In the others there was about one foot of mud upon hard gravel. The marly mud in every case was very dark. In Meyer's Lake 12 soundings were made. In eight cases hard sand under shallow mud was found, while in four cases mud over 12 feet in depth occurred. The hard bottom was in the northwestern part of the lake. The tests in Lorance Lake showed deep black mud in three places, fairly good marl in one and hard sand in one. Forty soundings, somewhat uniformly distributed about these lakes, disclosed only one locality where fairly good marl occurred.

Univalve shells were abundant in the lakes and there were a few bivalves, but the latter were not as common as at Lake Maxinkuckee.

HOUGHTON AND MOORE LAKES.

WORKABLE DEPOSIT.

These are two small lakes, lying about 50 rods apart and occupying parts of sections 7 and 18 (32 north, 1 east), Union Township. The north end of Houghton Lake is one and one-quarter miles south of the New York, Chicago & St. Louis (Nickel Plate) Railway, and the east side of Moore Lake is two and a quarter miles west of the Logansport Division of the Vandalia Railway. The lakes occupy nar-

row parallel valleys which trend northeast and southwest. Between the two lakes are two wooded islands, the southern and larger of which is about 15 feet above the level of the water. A low and narrow marshy tract separates the islands. Through this was formerly an artificial ditch, connecting the waters of the two lakes. This is now choked up with muck and decaying vegetation.

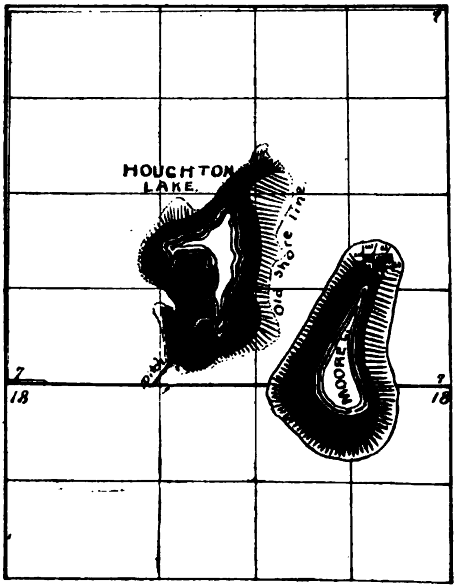

Fig. 60. Map of Houghton and Moore Lakes, Marshall County, Ind.

HOUGHTON LAKE.

This, the western lake, was drained in 1897, by a dredge ditch running to the southwest. The water was lowered about five feet and three-fourths of the former water area was laid bare. In September, 1900, the water remaining covered a little more than 13 acres, and ranged in depth up to 20 feet. The former lake bed was surrounded on all sides by low, marshy banks, which merged gradually upward into the higher cultivated fields. On the south there is a tamarack grove of 20 or more acres, and on the northeast an isolated ridge or island of gravel 15 to 20 feet in height, from which a good spring flows into the lake. To the northeast extensive marshy tracts extend for a half mile or more. These are covered with wire and other marsh grasses, and in the dryer seasons are mowed for hay.

Marl.—With the aid of Mr. Amos Osborne, of Culver, Indiana, who owns the greater portion of the old bed of Houghton Lake, 83 bores were put down in this former lake area. As no boat was available the present water area was not tested, but judging from the surrounding tests close to the water margin, there is no doubt but that marl more than 25 feet in depth underlies the whole of the water.

Over two-thirds of the former lake area, now dry, marl forms the surface. In many places this surface was so soft that in walking over it we sank six or eight inches. In other places it was too soft to walk over without miring down. Rank growths of bulrushes, *Scirpus lacustris* L., occurred over these softer springy portions. Of the 83 bores put down, for the most part 10 rods apart in each direction, 36 did not find the bottom of the marl with a 25-foot auger. These were, for the most part, on the south and west sides of the present water area, though a few of them were north of that area and east of the gravel island above mentioned. Twelve of the bores found the marl between 15 and 25 feet in thickness, while 12 others found it between eight and 15 feet deep. Of the remaining 23 tests, 11 showed six to eight feet of marl and seven of the others found between one and six feet. Except on about 15 acres of marsh in the northeast corner, not a single test within the border of the area recently covered with water failed to find marl. East of the present water area the marl between the water and wooded island is only from six to 10 feet in thickness except close to the water, where it increases to 18 feet. Just west of the gravel island north of the lake, it is but six feet in thickness over quite an area. West of the old lake bed, as shown on the map, there is a marsh area of six or eight acres, in which muck three to six feet thick overlies a marl bed from three to 10 feet in thickness. In one place in the ditch at the southwest corner the marl is over 28 feet thick, as the ditch is three feet deep and bottom was not reached with the auger. Wherever bottom of marl was reached gravel was found. It is estimated that, including the present water area, there are 50 acres in the old bed of Houghton Lake over which the marl will average 20 feet in thickness.

MOORE LAKE.

This lake lies east of Houghton Lake, and over half of its surface is in the southeastern quarter of section 7 (32 north, 1 east). It is about 200 rods long by 60 rods wide. According to the County Surveyor, it contains 92+ acres. This must include the area out to the meander lines, as there is probably not over 70 acres now covered

with water. There is a small island near the south end, and the water is nowhere over 15 feet deep, while three-fourths of its area is less than five feet in depth. The shores are everywhere low, and on the north, west and south are bordered by extensive muck-covered meadows. On the east a wooded ridge rises about 20 feet, back eight to 15 rods from the water's edge. A wide and deep dredged ditch already exists about 30 rods south of the southern margin of the lake, and to it a ditch can be joined for $35 which will lower the water of the lake five feet, and so drain three-quarters of its area.

MARL.—A large number of tests showed that at least two-thirds of the area of Moore Lake is underlain with a deposit of marl which will average 12 or more feet in thickness. In fact it may run in most places 20 feet or more, as our tests were made in a leaky boat, with a shovel as a paddle, so that only an 18-foot auger could be used. The large majority of the bores put down did not reach bottom in one to five feet of water. The best deposit of marl is found beneath the wide areas of shallow water on the south and west sides. Here in many places it was 17+ feet in thickness. Along the east shore, 100 to 150 feet out, it is from eight to 15 feet thick with gravel beneath. In the northeast corner there is a thick bed of muck overlying the marl, but everywhere else the muck was lacking.

With 50 acres in Moore Lake, averaging, at a low estimate, 12 feet, and the same area in Houghton Lake averaging 20 feet in thickness, there is here a first-class deposit of marl, located within two and one-half miles of two good railways. An analysis of an average sample, obtained by mixing the samples from the two lakes, gave the following percentage composition:

Calcium carbonate ($CaCo_3$)	89.22
Magnesium carbonate ($MgCo_3$)	2.73
Alumina (Al_2O_3)	.04
Ferric oxide (Fe_2O_3)	.20
Insoluble inorganic matter (silica, etc.)	2.02
Organic matter	4.15
Total	98.36

This shows the marl to be in every way suitable for cement making, the calcium carbonate being above the average and the magnesium carbonate and other impurities low.

ST. JOSEPH COUNTY.

References.—

1859.—Richard Owen, Geol. Reconn. of Ind., p. 199.

1873.—G. M. Levette, Fifth Ann. Rep. Geol. Surv. of Ind., p 456.

1898.—W. S. Blatchley, Twenty-second Ann. Rep. Ind. Dep. Geol. & Nat. Resources, p. 140.

1899.—Frank Leverett, Water Supply and Irrigation Papers, U. S. Geol. Surv. No. 21, p. 21.

St. Joseph County is bordered on the north by the State of Michigan, on the east by Elkhart County, on the south by Marshall and Starke and on the west by Laporte. It comprises an area of 477 square miles, the surface of which is diversified by prairies, marshes, "oak openings," and rolling timber lands. The "oak openings" are covered with a light sandy soil excellently suited to the raising of small fruits; the timber-lands possess a subsoil of clay, covered with a dark rich soil, which under proper cultivation and rotation of crops, yields all the cereals in abundance. The prairies, both old and young —for the marshes are but incipient prairies—where properly drained, are unexcelled for the raising of any farm products except wheat, which in places winter-kills.

The Kankakee River rises about two miles southwest of South Bend, and flows in a southwesterly direction through the county. The most of the marsh land adjacent to it has been or is being drained. The St. Joseph River is the principal stream within the county, entering it a little north of the middle of the eastern boundary, flowing westerly about 10 miles, and then northerly into the State of Michigan. On its great bend to the northward is the flourishing city of South Bend, possessing a population of almost 36,000, and noted for its manufactures, especially wagons and plows, which are shipped to all portions of the world.

Six important railways pass through the county: the Lake Shore & Michigan Southern; the Grand Trunk; the Michigan Central; the Indiana, Illinois & Iowa, commonly known as the "Three I;" the Logansport Division of the Vandalia, and the Chicago Division of the Wabash. The Baltimore & Ohio and Lake Erie & Western cross the southwestern corner, their junction with that of the "Three I" being at Walkerton, while the Michigan Division of the "Big Four" cuts the northeastern corner. Most excellent transportation facilities are thus furnished in every direction.

There is not an outcrop of rock in the county, the entire surface being covered with glacial drift which will probably average 200 feet

in thickness. The only place where this drift has been pierced to the underlying stratified rock is at South Bend, where it was 137 feet thick. This, however, was in the valley of the St. Joseph River and only 725 feet above tide, or fully 150 feet lower than the uplands in the southeastern portion of the county. The levels of the more important railway stations in the county show the following altitude in feet, above tide: Lakeville, 837; Mishawaka, 700 to 743; Notre Dame, 710; Osceola, 736; South Bend, 708 to 726; Walkerton, 711; Warren, 730.

The drift over about one-half of the county is a gravel plain formed by the outwash from the ice sheet. "In the northwestern portion of the county the outwash is from the Valparaiso moraine, and the plain descends from about 800 feet at the border of the moraine to 725 feet at the border of the Kankakee marsh. In the southwestern portion of the county the outwash is westward from the Maxinkuckee moraine of the Saginaw lobe, and there is a similar descent from the moraine to the Kankakee marsh. In the northeastern portion of the county there is an extensive gravel plain along the St. Joseph River, whose head is in southern Michigan in a later moraine of the Saginaw lobe. The southeastern part of the county is occupied by a till plain which borders the Maxinkuckee moraine on the east. The Maxinkuckee moraine passes diagonally across the county from the southwest to the north border and has a width of about five miles. It is interrupted by a gap at the St. Joseph River near South Bend two or three miles in width. The highest portions of this moraine stand fully 300 feet above Lake Michigan, or about 900 feet above tide."*

The lakes of St. Joseph County are small in size and most of them are rapidly becoming extinct. But one deposit of marl of good workable area and thickness is located in the county. That is at Chain and Bass lakes, west of South Bend, and is fully described below.

NOTRE DAME LAKES.

Thick Deposit, Mostly Beneath Deep Water.

These lakes, two in number, lie just northwest of Notre Dame College, in section 36 (38 north, 2 east), a little more than a mile northeast of South Bend. St. Joseph's Lake, the larger of the two, has an area of about 65 acres, and a maximum depth on the west side of 25 feet. The water area of St. Mary's Lake is a little more than 30 acres. The two lakes are separated by a stretch of low ground containing 10 or more acres. In the past this was covered with water, forming one continuous body or lake.

*Levette, loc. cit., p. 21

MARL.—The marl deposit in and about these two lakes is of especial interest in that it furnished the carbonate of lime material to the first, and for more than 20 years the only, Portland cement factory in Indiana. At St. Mary's Lake the water deepens abruptly and close to shore. The marl extends back several rods from shore, and it is mainly this shore marl that has been worked in the past

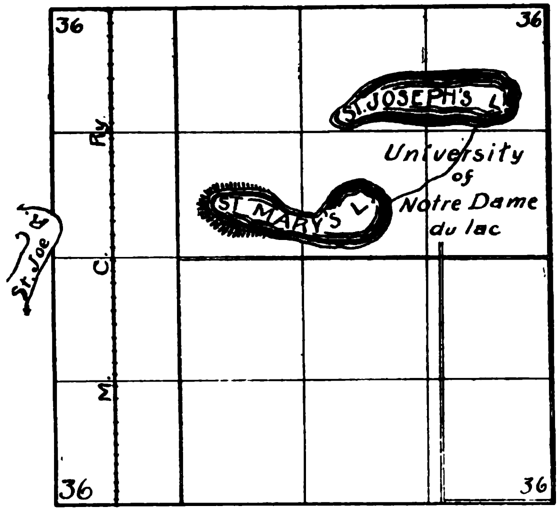

Fig. 61. Map of Notre Dame Lakes, St. Joseph County, Ind.

for the cement factory at South Bend. The entire lake, as well as that of St. Joseph, is underlain with a thick deposit. This, where tested, was everywhere beyond reach of auger and, it is claimed, has an average thickness of more than 30 feet. The marl was secured by dredges, the cut of one of which is shown on plate IV. It was piled up on the shore and hauled to the factory as needed. The University received a royalty or specified sum per ton, and at the same time had its lake deepened and cleaned up.

An analysis of the marl made by Dr. Noyes proves it to be of excellent quality, its percentage composition being as follows:

Calcium carbonate	91.62
Magnesium carbonate	4.02
Alumina (Al_2O_3)	0.05
Ferric oxide (Fe_2O_3)	0.07
Calcium sulphate	0.14
Insoluble portion (silica)	0.19
Organic matter	2.25
Total	98.34

CHAIN AND BASS LAKES.

WORKABLE DEPOSIT.

The basin occupied by the remnants of these lakes is in sections 35 and 36 (38 north, 1 east), and sections 1, 2, 11 and 12 (37 north, 1 east), Warren Township, about five miles west of South Bend. The Lake Shore & Michigan Southern Railway runs over a high grade and trestle be-between the two lakes, while the Michigan Division of the "Three I" is but a short distance south of Chain Lake.

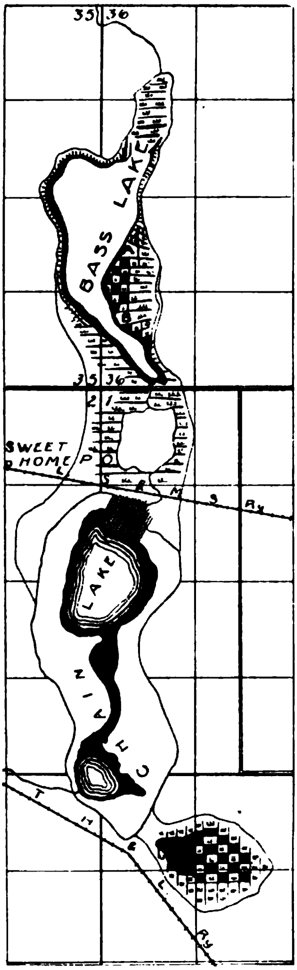

Fig. 62. Map of Chain and Bass Lakes, St. Joseph County, Ind.

Chain Lake has been partially drained and at present consists of two small bodies of water connected by a rather broad channel and lying between the railways above mentioned. Around parts of the larger body the shore is so low as to be readily flooded by a slight rise in the lake, while elsewhere the muck has built up the surface two or three feet above the former level of the water. Southeast of Chain Lake, between Chain and Bass lakes, and northeast from Chain Lake, are flat stretches that at one time, though not recently, formed a part of the water area of the lake. Outside of these areas the hills are rather abrupt, though not high.

Bass Lake lies north of the L. S. & M. S. Railway and is separated from Chain Lake by a low marshy tract, of 30 or more acres, which lies between the railway and the grade of a wagon road. The extreme length of the present water area of Bass Lake is a little over one-half mile, while the average width is not more than 30 rods. The southern half of the water area is only about one-half the width of the northern, a wide, grass covered marsh, three feet above the water level, lying on the east side south of the northern and wider main body of water. On the north and south the shores are low and

marshy. On the east of the main water area a marsh a few rods in width separates the edge of the water from the steep slope of a prettily wooded ridge, 30 to 40 feet in height. The western shores rise more gradually from the edge of a narrow marsh into cultivated fields whose surface is 20 to 30 feet above the water. The greatest depth of water in Bass Lake is 32 feet, but more than one-half of the water area is less than 10 feet deep.

MARL.—With the exception of a strip five to eight rods wide, which lies next to the hills on the east, the present water area of Bass Lake is underlain with marl which will average over 12 feet in thickness. In four-foot water the marl runs from 15 to 18 feet in thickness. There is no muck over the marl beneath water. North of the main body of water is an extensive marsh in which a thick bed of muck overlies most of the marl. Several bores showed the marl to run from six to 12+ feet and the muck from three to five feet in thickness. The marsh on the southeast, about 10 acres in area, is underlain with marl which, at (A), is 10 feet thick at the water's edge, while 10 rods back from the water it is six feet thick beneath two and a half feet of muck. On the east shore of the southern end of the lake, at (B), the marl was 19+ feet thick at the edge of the water, with about one foot of thin muck at the surface. Ten rods north, on the marsh, the muck was two and a half feet thick above 10 feet of marl. Ten rods southeast of (B) the muck is three feet and the marl nine and a half feet, while 15 rods farther southeast at the southeast corner of the lake the marl is 11 feet beneath the same depth of muck. Over most of the marshy tract between the wagon road and the L. S. & M. S. Railway the marl is 16 to 18 feet thick beneath two to four feet of muck. The water area of this tract was not tested, as no boat was available.

Examination from a boat on Chain Lake showed marl to below 16 feet at every point, and it is claimed that in the center of the lake, tests with a 25-foot pole failed to reach the bottom of the marl. On the low west shore between the lake and the L. S. & M. S. Railway the marl showed a depth of 13 feet and over, with no cover. In the southern part of the original basin and the partly enclosed arm to the southeast, tests showed from one to five feet of muck, with marl beneath to below 16 feet. The muck, of course, is thin near the water and increases in thickness at the expense of the marl as the shore is approached. An analysis by Dr. Noyes of an average sample of the marl from Chain and Bass lakes shows the following percentage composition:

Calcium carbonate ($CaCo_3$)	87.92
Magnesium carbonate ($MgCo_3$)	2.64
Ferric oxide (Fe_2O_3)	.20
Alumina (Al_2O_3)	.10
Calcium sulphate ($CaSo_4$)	.23
Insoluble inorganic matter (silica, etc.)	3.10
Organic matter	4.18
Total	98.37

This analysis proves the quality of the marl to be excellent for cement making purposes.

It is estimated on what was seen and on reports received that the marl covers at least 225 acres in and around Chain Lake alone, while the area in and around Bass Lake is fully one-half as much. The proximity of railways and the city of South Bend, renders the deposit a valuable one and well worthy of development.

CEDAR AND MUD LAKES.

Not a Workable Deposit.

These lakes occupy parts of sections 2, 11, 12, 13 and 14 (38 north, 1 east). They lie on or just south of the Michigan-Indiana line, about eight miles northwest of South Bend, the northern two-thirds of Cedar Lake being in Michigan.

Cedar Lake furnishes a typical example of a lake whose water area has been encroached upon by decaying vegetation until it has become almost extinct. Twenty years ago, according to the report of persons living near, its entire basin of 80 or more acres was covered with water to a depth of 20 to 30 feet. Then there was no aquatic vegetation except along the south shore. Now the southern half is a vast morass of muck and spatterdock, with water nowhere more than six inches in depth. The western margin for one-third the distance across the lake is similarly filled. Many floating islands or moving morasses of muck rise nearly to the surface in other parts of the lake, so that its clear water area is but little over 15 acres, and its deepest water only about 12 feet.

A fine wooded ridge, much frequented by picnic and fishing parties, and with a gravelly margin at the water's edge, rises 20 or more feet along the north half of the east side. The banks on the north and west are lower, while the southern shores are marshy. The lake has been for years a favorite resort for the fishermen of South Bend, bass, blue-gills, perch, croppies and other food and game fishes

being abundant. Among the more common of the many plants growing in the water in September, 1900, were the following:

TYPHA LATIFOLIA L. **Broad-leaved Cat-tail.**
Close to margin along south and west shores.

SPARGANIUM EURYCARPUM Engelm. **Common Bur-reed.**
Quite common with the above.

POTAMOGETON NATANS L. **Common Floating Pondweed.**
Frequent in water from three to seven feet in depth.

POTAMOGETON HETEROPHYLLUS Schreb. **Diverse-leaved Pondweed.**
With the above.

POTAMOGETON PECTINATUS L. **Fennel-leaved Pondweed.**
Wholly submerged in three to eight feet of water.

TRIGLOCHIN PALUSTRIS L. **Marsh Arrow-grass.**
In shallow water on north and west shores.

ALISMA PLANTAGO-AQUATICA L. **Water Plantain.**
Common in the marshy southern area.

SAGITTARIA GRAMINEA Michx. **Grass-leaved Arrow-head.**
Along the north and east shores in shallow water.

PHILOTRIA CANADENSIS (Michx.) Britton. **Water-weed; Ditch-weed.**
At the bottom of all water two to four feet in depth.

VALISNERIA SPIRALIS L. **Tape grass; Eel-grass.**
Common in water three to five feet deep.

PELTANDRA VIRGINICA (L.). **Green Arrow-arum.**
Along the margins in company with arrow-head, water-plantain and pickerel-weed.

SPIRODELA POLYRHIZA (L.). **Greater Duckweed.**
Covers the surface in many places.

ERIOCAULON SEPTANGULARE With. **Seven-angled Pipewort.**
In abundance on the floating islands of muck. Noted elsewhere only at Bass Lake, Starke County, and Round Lake, Whitley County.

PONTEDERIA CORDATA L. **Pickerel-weed.**
In one to two feet of water on the south and west shores.

BRASENIA PURPUREA (Michx.). **Watershield.**
Everywhere in water three to five feet in depth.

Nymphæa advena Soland. Spatterdock; Yellow Pond Lily.
Covers the southern half of the lake basin.

Castalia odorata (Dryand) White Water Lily.
Along the margins of the northern and deeper waters; common also with the preceding where the water was of sufficient depth.

Utricularia vulgaris L. Greater Bladderwort.
Common in water up to six feet in depth.

Utricularia purpurea Walt. Purple Bladderwort.
Frequent in water four to six feet in depth, the purple flowers floating just at the surface. Not noted by the writer elsewhere in the State, but has been reported from Lake County.

Numerous other aquatic plants, especially rushes and sedges, were seen during the two hours spent on this lake. The above were the ones which in the past have formed most of the muck which has replaced the water. No one who has not visited a lake like Cedar can realize how varied the kind and how abundant the individuals of plant life which can flourish in water. It is one of the best examples at present in Indiana, of a dying lake—an incipient marsh. Here one can see in actual progress many of those intermediate stages and processes which in time change a body of fresh water into a body of land without the aid or intervention of man.

The northern edge of the basin of former Mud Lake lies south of that of Cedar Lake about one-third of a mile. Its former water area was over 300 acres and its outline was very irregular. Now by draining and by the encroachment of vegetation it has become a vast marsh, with not more than 30 acres of water, and that shallow and occupying two or three small isolated areas. In places where the local residents fished for bull-heads and bass a score of years ago are now cultivated cornfields. The vegetation in and about the remaining water area is not nearly so dense or so varied in character as at Cedar Lake.

Marl.—A trace of marl was found only in two places in Cedar Lake. In general the bottom of muck was beyond reach of an 18-foot auger, though along the east shore gravel was struck beneath six feet of muck 100 feet from the bank.

No boat was available for exploring the water area of Mud Lake. A number of tests in the marsh on the north and west shores disclosed only muck, which varied in thickness from three to 18+ feet.

GOOSE OR SONSLEY'S LAKE.

Not a Workable Deposit.

This lake or marsh lies a little over two miles north of North Liberty in sections 9, 10, 15 and 16 (36 north, 1 east), Greene Township. It is less than a mile from the "Three I" railway and about the same distance from a gravel pit switch of the Grand Trunk Railway. Sonsley's Lake formerly covered most of section 16, a small area in the east part of section 17, a small area in sections 9 and 10, and ex-

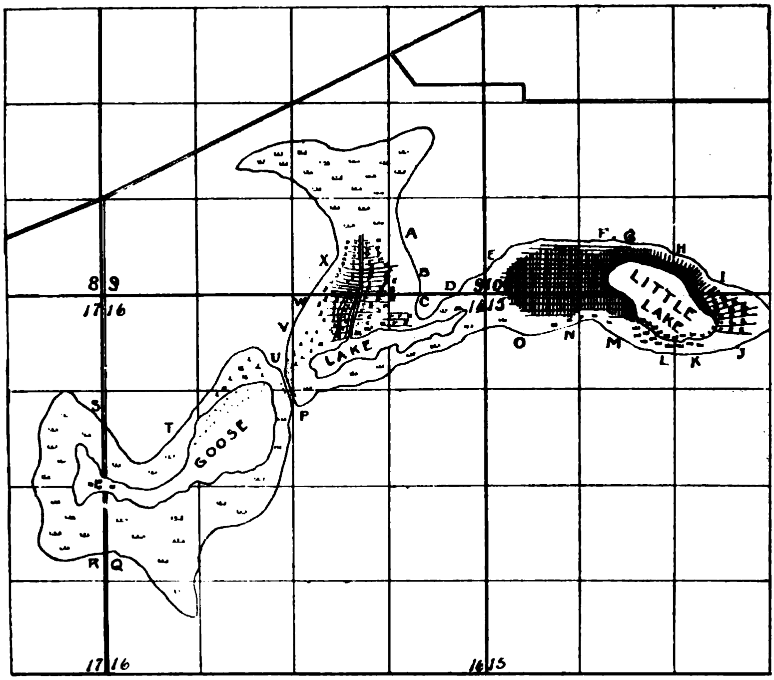

Fig. 63. Map of Little and Goose Lakes, St. Joseph County, Ind.

tended east to include most of the northern half of section 15, now in part occupied by what is called Little Lake. The total area of lake and marsh is not far from 400 acres. When examined, Little Lake had an area of about 30 acres, and the remnant of Goose or Sonsley's Lake covered 40 or 50 acres.

Some years ago the whole area, now occupied by the lakes and marsh, except Little Lake, was drained, but the filling up of the drain has allowed several feet of water to accumulate over a considerable area in the western part of section 16, and a small area in the eastern

part of the same section. Between these two water areas an esker of glacial origin stretches across the lake basin. It appears as a sandy bar rising four or five feet above the water level. Goose Lake is very shallow, Little Lake somewhat deeper. The surrounding bluffs are usually rather abrupt and 15 to 20 feet high. A slight rise in the water would cause it to cover no small part of the area around Goose Lake.

MARL.—Lack of a boat prevented examination of the area covered by water, except around the edges. It is reported that drillings made by prospectors through the ice showed about 45 acres of marl with a maximum thickness of 30 feet. Drillings near the raised road along the west line of section 16 showed from four to 10 feet of muck with traces of marl. Tests along the north side of the larger water body showed only sandy bottom in shallow water, with from three to four feet of muck over the sand back from the water's edge.

Most of the area east of the sand bar was dry. Near the sand bar the ground is sandy. Then out from (V) there are three to four feet of muck until, as the ditch from the north is approached, marl sets in, soon running to below reach of drill, while the muck thins down to two feet or a little less. Between (W) and (C) the muck runs up to seven feet toward the shore without marl, but for a few hundred feet from the ditch either side the muck is about three feet thick, with marl thickening to below end of drill. This continues to the north with narrowing width into section 9, but toward (A) thins down, drillings between (A) and (X) showing an average of only four or five feet.

Just east of the mouth of the drain, 10+ feet of muck was found, and out from (D) only muck occurs, but southwest of (C) there is a good depth of marl under two feet of muck.

Passing east into the basin of Little Lake there is a good deposit of marl between the section corner and the lake (E-F-N-O-E). Over most of this area the muck was from one to one and a half feet thick, running out entirely toward (G), with marl to below reach of drill. Near the banks the marl thins out and the muck gets thicker. Tests around the north, west and southwest sides of Little Lake showed clear marl to below reach of pole, but on the south side it is covered by a greater depth of muck, which toward the east end of the lake entirely replaces the marl. East of the lake the muck rapidly increases to a thickness of nine or 10 feet, with very mucky marl underneath.

On the whole, this deposit, while extensive, appears to be of small value, due to the depth of muck overlying much of the marl and the poor quality of the latter.

RUPEL'S LAKE.

NOT A WORKABLE DEPOSIT.

This is a small lake lying just southeast of North Liberty, in section 33 (36 north, 1 east). It appears to be shallow and is surrounded, except on the west, by flat marshy land.

MARL.—No marl was found immediately east or southeast of the lake. Along the ditch which enters the lake from the southwest marl occurs with a thickness ranging from 0 to 10 feet. It is everywhere overlain by at least three feet of muck, often sandy. The marl appears to extend only a short distance east of the ditch. Over the marsh just west of the lake only muck was found, but

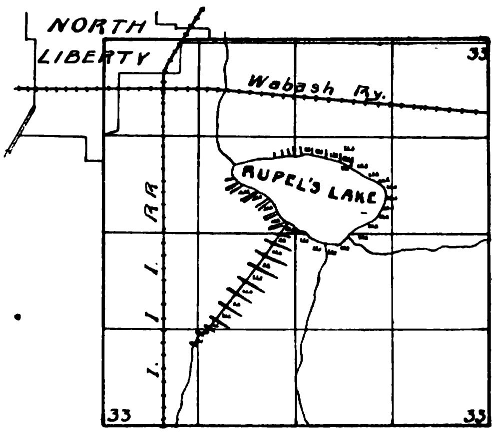

Fig. 64. Map of Rupel's Lake, St. Joseph County, Ind.

further back in the corn field marl of good depth occurs under from four to six feet of muck. It is said that 22 feet of marl has been found here. It seems, however, to occupy a very limited area.

A little marl was found on the north side of the lake, in one place the bore showing six feet under three and a half feet of muck. In places the marl reaches the surface. A series of tests back from the lake at one point showed 10 feet of muck at water's edge; 25 yards back, three and a half feet of muck, six feet of marl; 50 yards farther, seven feet of muck, trace of marl; 50 yards farther, 10+ feet of muck.

KANKAKEE MARSH DEPOSITS.

Not of Workable Size.

Three miles southwest of South Bend a dredged ditch has, for some distance, replaced the original channel of the Kankakee River through the marsh. It was reported that in digging the ditch large quantities of marl had been struck in two places, viz., in section 25 (37 north, 1 east), and in section 20 (37 north, 2 east). At the first named place we failed to find the marl, though we examined all the ditches and made many drillings. The muck here ranged from three to six feet in thickness.

At the second locality marl was found in the north half of section 20 and the south half of section 17, on the land of Hon. Clem. Studebaker, between the Grand Trunk and "Three I" railways. The Kankakee ditch was first driven into the northwest quarter of the northeast quarter of section 20, where it ran into marl to such an extent that the line surveyed had to be abandoned and a new direction taken. The greatest depth of marl found at this point of abandonment was eight feet under three feet of muck. Going back nearly a quarter of a mile the ditch was driven east until the right of way of the "Three I" railway was reached; it continued along that for nearly a quarter of a mile, then turned north again. Marl shows above the water in the ditch at two places, where it runs beside the railway, the marl being five feet deep under four feet of muck at the best, though only a few feet back from the edge of the ditch the muck is seven feet thick and marl only three feet. The marl in this marsh becomes very white after drying, and the following analysis by Dr. Noyes shows that it has an excellent composition:

Calcium carbonate ($CaCo_3$)	91.30
Magnesium carbonate ($MgCo_3$)	2.90
Ferric oxide (Fe_2O_3)	.08
Alumina (Al_2O_3)	
Calcium sulphate ($CaSo_4$)	.22
Insoluble inorganic matter (silica, etc.)	.82
Organic matter	3.88
Total	99.20

Tests in the northwest part of the southwest quarter of the northeast quarter of section 20 showed from four to five feet of muck with from 0 to three and a half feet of marl beneath. In the southwest of the southeast of section 17 the muck runs from eight to nine feet deep and overlies from one to three feet of marl. In the south-

east quarter of the southwest quarter of section 17 and northeast quarter of the northwest quarter of section 20 the muck measured from seven to nine feet and the thickest marl a little over three feet.

An interesting feature of the deposit in these marshes is the pockety nature of the marl, as indicated in the banks of the ditch, and the association of these pockets with chalybeate springs.

Marl was reported as having been struck in ditching just west of Walkerton. An extended series of tests were made, but all the marl that was found was under nine feet or more of muck. Some of the small marshes east of Walkerton were also examined, but only traces of mucky marl, generally overlain by a considerable depth of muck, were found.

LAPORTE COUNTY.

References.—

1859.—Richard Owen, Geol. Reconn. of Ind., p. 201.

1873.—G. M. Levette, Fifth Ann. Rep. Geol. Surv. of Ind., p. 461.

1875.—Id., Seventh Ann. Rep. Geol. Surv. of Ind., p. 478.

1899.—Frank Leverett, Water Supply and Irrigation Papers, U. S. Geol. Surv., No. 21, p. 18.

Laporte County is in the third tier of counties from the western line of Indiana, and lies adjacent to the south border of the State of Michigan. Its northwestern corner is bordered by the shore of Lake Michigan for a distance of seven miles. It is bounded on the east by St. Joseph, on the south by Starke and on the west by Porter County. The Kankakee River forms a small portion of the eastern boundary and then cutting across the southeastern corner forms the greater part of the boundary line between Laporte and Starke counties. Mill Creek and several smaller tributaries drain the southern half of the county into the Kankakee, while north of the continental divide, which passes northeast and southwest through the center of the county, are several small streams which flow into Lake Michigan.

Transportation facilities are most excellent, six railways crossing the county from east to west, two from north to south and one from southeast to northwest, thus furnishing an outlet in every direction.

The area of the county is 562 square miles. Of this the northern third is somewhat broken and hilly and was formerly covered with timber. The central and southern portions contain about 200 square miles of fine prairie and a large area of Kankakee marsh land, much

of which has been drained, and now forms excellent grazing and farming lands. The entire surface is of glacial origin, the Valparaiso moraine, with a width of six miles, passing northeastward across the northwestern corner of the county. The crest of this moraine lies from 225 to 300 feet above the level of Lake Michigan. This moraine "rises very abruptly on its northwest border above the low plain which lies between it and Lake Michigan, but on its southeast border a gravel outwash from the moraine is built up nearly to the level of the crest, and the descent is gradual from the moraine to the Kankakee marsh. The marsh stands fully 100 feet above Lake Michigan in eastern Laporte County and about 75 feet at the western border of the county. It is, therefore, 150 to 200 feet or more below the crest of the moraine. The gravel plain makes a descent of 75 or 100 feet in the interval of eight or 10 miles between the moraine and the marsh.

"On the low plain bordering Lake Michigan, in the northwestern part of the county, there are series of narrow till ridges or feeble moraines which govern the drainage of that region to a marked degree, though having a relief of but 30 to 50 feet. On the immediate border of the lake there are prominent dunes, rising in places to a height of 150 feet above lake level."*

The thickness of the drift is known at but three places where gas well borings have penetrated to the underlying stratified rock. These are at Laporte, where it is 295 feet thick; La Crosse, 38 feet, and Michigan City, 250 feet. The surface levels at the more important railway stations are as follows in feet above tide: Hanna, 703; Haskell's, 771; La Crosse, 675; Laporte, 812; Michigan City, 600; Oakwood, 727; Otis, 765; Rolling Prairie, 820; Stillwell, 731; Wanatah, 730; Westville, 789.

The lakes of Laporte County are few in number and are, for the most part, situated near the crest of the divide. But two of them, Du Chemin and Fish, contain workable deposits of marl. Those near Laporte have, for 35 years, furnished immense quantities of ice for shipment to Indianapolis and other cities.

HUDSON OR DU CHEMIN LAKE.

Workable Deposit.

This lake lies about 11 miles northeast of Laporte, in sections 28, 29 and 30 (38 north, 1 west), and is just west of Hudson station, on

* Leverett, loc. cit.

the Lake Shore & Michigan Southern Railway. The total length of the lake from east to west is nearly two miles and the average width about one-half a mile. The area is 750 or more acres.

MARL.—The whole lake appears to be underlain by marl, but, for the most part, it is not very thick, being thickest toward the west end. West of the island the lake was nearly dry when examined in September, 1899, there being only a small body of water, mostly in the southwest lobe, and much of that was less than a foot deep. Tests at one point showed the marl to have the following depths at the given distances from shore: At five yards from shore, marl two

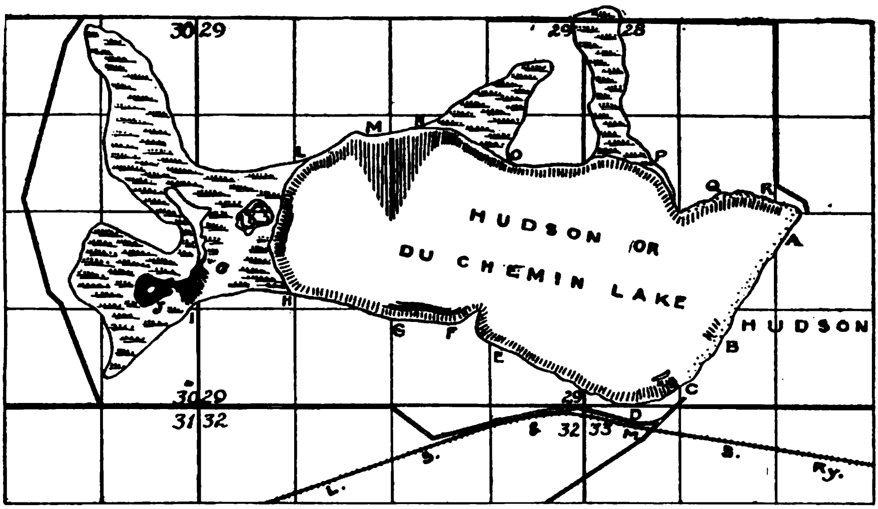

Fig. 65. Map of Hudson Lake, Laporte County, Ind.

feet; at 10 yards, two and a half feet; at 15 yards, four feet; at 20 yards, seven feet; at 25 yards, nine and a half feet; at 30 yards, 12½ feet; at 50 yards, 14 feet. At other points the space between the water and shore was inaccessible. In the water area no solid marl was found, but a mushy mixture of marl and muck, through which the drill would sink rapidly of its own weight to its full length. The most of the marl here not only appeared to be of poor quality, but too soft to be handled except by a pipe.

In the main body of the lake the marl is not so thick, but more solid, and apparently of much better quality. Just east of the island it ran 10+ feet thick in seven feet of water, but the average will hardly run over five or six feet. Only a few of the tests in less than 10 feet of water failed to find the bottom of the marl at depths of 16 feet or less. At the east end the marl runs from seven to nine

feet thick in from three to five feet of water, but along most of the north side in that depth of water the marl runs from four to six feet thick. In deeper water the marl shows a tendency to become thinner. Thus at one point there was but one foot of marl in 11 feet of water, though but a short distance away nine feet of water overlay seven feet of marl. At another point 13 feet of water gave but one and a half feet of marl, though six feet of water between that and shore gave six feet of marl.

Along the south shore the marl runs a little thicker, few of the tests showing less than six feet, and a few on the edge of deep water not reaching the bottom. At the southeast end of the lake near the hotel the marl runs thin or in places runs out, being replaced by muck.

On the whole, the large acreage more than offsets the thinness of the bed, and a fair workable deposit may be said to occur beneath the shallow water area. If the lake should ever be lowered a much larger quantity would, without doubt, become available.

CLEAR, PINE, STONE AND FISH-TRAP LAKES.

Not a Workable Deposit.

Of the lakes lying north and northwest of Laporte the following were visited: Clear, Stone, Pine, Mud and Fish-trap lakes. Of these the first three are connected by channels and furnish water to the Laporte waterworks, situated on the western lobe of Clear Lake. The effect of this has been to lower the surface of the lakes a few feet, yet enough to convert considerable areas of them from lake to marsh or dry land.

CLEAR LAKE.

This lake lies north of and adjoining the city of Laporte. In 1875, Dr. G. M. Levette wrote of it as follows: "Clear Lake has uniformly low, sandy shores, and sustains a scattered growth of vegetation in the shallow portions. The water owes its turbid, dirty green color to the great quantity of suspended organic matter, confervae, and perhaps minute animal organisms. Just west of the center of this lake, for a space of two or three acres, the water is only a few inches deep; this may have been a small hill in the original bed of the lake, but the fishermen insist that it has formed there within a few years; that being true and no currents in the lake, the cause of the accumulation is not clearly understood.

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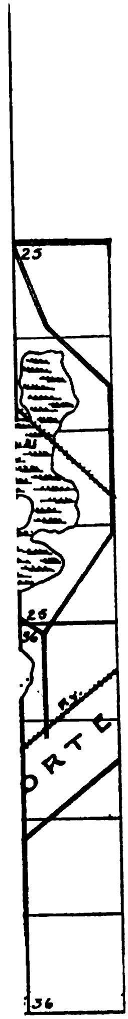


"A careful search with the sounding line, for half a day, failed to find any water more than nine and a half feet deep. Forty-two soundings were made, showing from four to nine and a half feet of water, and the temperature ranged from 66 degrees at the surface to 65 degrees at the bottom, in deepest parts. Notwithstanding the high temperature of this shallow basin of turbid water, it is more resorted to for line fishing from boats than any other lake in the vicinity."

In September, 1899, the irregular area formerly occupied by Clear Lake was nearly all a mud flat. A small pool occupied the center of each of the end lobes and a somewhat larger body of water was in the central basin. This was shallow, and except for some sandy bottom on the south side, has a bottom of muck extending at all points tested to over 16 feet. No marl was found.

PINE LAKE.

This lake lies two miles northwest of Laporte. It is the largest lake near that city, and is about one and a half miles long in a north and south direction and nearly three-quarters of a mile in width. On the east and west sides the hills, composed almost wholly of sand, rise from 30 to 40 feet above the water.

In 1875 Dr. Levette took the following temperature soundings, beginning on the east side about 500 feet from shore and moving north; depth and temperature at intervals of 300 feet:

1. Bottom at 41 feet, temperature.................. 59° F.
2. Bottom at 34 feet, temperature.................. 61° F.
3. Bottom at 20 feet, temperature.................. 63° F.
4. Bottom at 17 feet, temperature.................. 64½° F.
5. Bottom at 12 feet, temperature.................. 67° F.
6. Bottom at 10 feet, temperature.................. 67° F.
7. Bottom at 14 feet, temperature.................. 66° F.
8. Bottom at 38 feet, temperature.................. 60° F.
9. Bottom at 40 feet, temperature.................. 61° F.
10. Bottom at 39 feet, temperature.................. 61° F.
11. Bottom at 30 feet, temperature.................. 62° F.
12. Bottom at 25 feet, temperature.................. 64° F.
13. Bottom at 40 feet, temperature.................. 61° F.
14. Bottom at 12 feet, temperature.................. 66½° F.

Returning to the ninth station and moving toward the southwest corner of the lake, a second line of soundings, the same distance apart, were taken, which resulted as follows:

1. Bottom at 50 feet, temperature.................. 56° F.
2. Bottom at 40 feet, temperature.................. 61° F.
3. Bottom at 45 feet, temperature.................. 59° F.
4. Bottom at 42 feet, temperature.................. 60° F.
5. Bottom at 38 feet, temperature.................. 61° F.
6. Bottom at 30 feet, temperature.................. 62° F.
7. Bottom at 52 feet, temperature.................. 55° F.

The lowering of the surface of Pine Lake in recent years has divided it into two bodies separated by a narrow sandy channel. The water is deep and clear, the southern arm having a depth of 50 feet in front of the ice houses and a depth of 38 feet very close to shore near the eastern end of the tongue of land separating the two lobes.

Dr. Levette and Mr. Caleb Cooke made a collection of fishes in Clear and Pine lakes in 1875. These were afterward studied and classified by Dr. D. S. Jordan; with their nomenclature brought up to date, the list of 21 species is as follows:

LIST OF FISHES KNOWN TO OCCUR IN CLEAR AND PINE LAKES.

1. *Amieurus natalis* (Le S.). Yellow Cat.
2. *Amieurus nebulosus* (Le S.). Common Bullhead; Horned Pout.
3. *Noturus flavus* Raf. Stone Cat.
4. *Erimyzon sucetta oblongus* (Mitch.). Chub Sucker; Sweet Sucker.
5. *Pimephales notatus* (Raf.). Blunt-nosed Minnow.
6. *Notropis megalops* (Raf.). Common Shiner; Silverside.
7. *Hybopsis storerianus* (Kirtland). Kirtland's Minnow.
8. *Hybopsis kentuckiensis* (Raf.). Horny Head; River Chub.
9. *Notemigonus chrysoleucus* (Mitch.). Golden Shiner.
10. *Fundulus diaphanus menona* (Jor. and Copel.). Common Killifish.
11. *Umbra limi* (Kirtland). Mud Minnow.
12. *Lucius vermiculatus* (Le S.). Little Pickerel; Grass Pike.
13. *Labidesthes sicculus* Cope. Brook Silverside; Skipjack.
14. *Chænobryttus gulosus* (Cuv. and Val.). War-mouth; Red-eyed Bream.
15. *Lepomis cyanellus* (Raf.). Green Sunfish.
16. *Lepomis pallidus* (Mitch.). Blue Gill; Blue Sunfish.
17. *Lepomis gibbosus* (L.). Common Sunfish; Pumpkin-seed.
18. *Micropterus dolomieu* (Lacépède). Small-mouthed Black Bass.
19. *Etheostoma eos* (Jor. and Copel.). Sunrise Darter.
20. *Etheostoma microperca* Jor. and Gil. Least Darter.
21. *Perca flavescens* (Mitch.). Yellow Perch; Ringed Perch.

MARL IN PINE LAKE.—The northern arm of Pine Lake showed no marl. The bottom at the eastern end is sandy. Around the rest

of the shore is muck having a depth of from three feet to over 13 feet. The southern arm has hard bottom under most of the shallow water of the eastern half. A narrow westward extension of the lake was at the time of our visit out of water, while a considerable area just east of this was dry. This showed some marl, most of the tests in this area revealing from a few inches to seven feet or more. Around the edges some bare marl is exposed, but it is generally only a few inches thick. As the marl increases in depth it comes to have muck over it, the muck usually about equaling the marl in depth, so that where the marl is over seven feet deep it is overlain by nine feet of muck. In quality the marl is inferior, most of it showing a considerable admixture of muck.

STONE LAKE.

This lake lies about one mile northwest of Laporte and is about three-quarters of a mile long by one-half mile broad. In 1875 Dr. Levette wrote of it as follows: "Stone Lake is nearly surrounded by sandy hills from 20 to 40 feet high, and is one of the most beautiful sheets of water in the county. Why it should be called 'Stone' Lake is quite incomprehensible, as no rock of any description is visible in or near it; not a single pebble was seen in the clean, well washed sand which constitutes the bottom, the shores and the adjacent hills. The water is very free from suspended matter, and so clear that shells can be distinctly seen resting in their oozy bed, under 20 feet of water.

"All the eastern half of the lake is shallow, varying in depth from six to 10 feet; over a great part of which aquatic grasses grow luxuriantly, reaching, in many places, to the surface of the water. In the western half of the lake, near the high bold shore, the water is deeper, reaching 42 feet at the deepest point found by the sounding line."

The eastern lobe of this lake, including its former connection with Pine Lake, is now dry. This area showed only a very small deposit of fair marl, but even it was under 14 or more feet of muck. Otherwise all tests found only muck to a depth of 16 feet or over, except just at the shore. In a few places along the south shore the bottom was sandy; otherwise it was of muck which runs from three to seven feet near shore, but is deeper at the western end of the lake.

FISH-TRAP LAKE.

The former basin of this lake is now mostly a mud flat, though the water is reported as 20 feet or more deep over a narrow strip on the

east and north sides. Drillings showed only muck at the bottom of the lake, ranging in thickness from three feet to a depth of 10 feet near the center. What was once Mud Lake is now dry and partly under cultivation.

Horseshoe Lake, which was not visited, is also reported to be, at present, mainly an impassable mud flat or weedy marsh, though in a few places the water reaches a depth of 20 or more feet.

FISH LAKE.

Workable Deposit.

This lake lies in the east central part of Laporte County, in sections 16, 17, 20 and 29 (36 north, 1 west). Narrow channels divide it into four basins known as the Upper and Lower Fish lakes and Upper and Lower Mud lakes, while east of the last named is an area known as Goose Lake, which is dry much of the year. The two Fish lakes have each an area of about 100 acres and a maximum depth of 40 feet of water. The shallow water belt along shore is narrow, as a rule, though more irregular and wider in the Lower Lake than in the Upper. The two Mud lakes were, when examined in September, 1899, little more than swamps. Goose Lake was dry at the time, though it is said to have two feet of water over it in the Spring. The banks are everywhere less than 20 feet high. East of Goose Lake there is an extensive flat. The Grand Trunk Railway just touches the north end of Fish Lake, while the Chicago Division of the Wabash Railway runs only half a mile south of the south end.

Marl.—Upper Fish Lake shows marl all along the shore. It usually sets in, in less than two feet of water. Along the north and northeast shores the marl is over 12 feet deep in two feet of water, and at most points runs from three to eight feet in that depth of water. Beyond that depth the marl reached to below reach of drill.

Lower Fish Lake shows mostly muck just at the shore line, though often with marl beneath. By the time the water has reached a depth of four feet the marl was usually clear and extended to beyond reach of a 16-foot drill.

The water area of Mud lakes was not examined, but drillings on the east shore showed 13 feet of marl, suggesting the presence of a considerable body of marl beneath the water.

Goose Lake has an area of probably 160 acres. Though overflowed in the wet season, it becomes dry in the summer, at which time it shows a large area of bare marl, sparingly covered with bul-

rushes. In the center of this area the bottom of the marl could not be reached with our drill, though it was thought to be less than 20 feet. Away from the center the marl showed an average depth of about 10 feet. Between Goose Lake and Fish Lake the marl runs from two to 10 feet or more thick, but is, in part, overlain by muck,

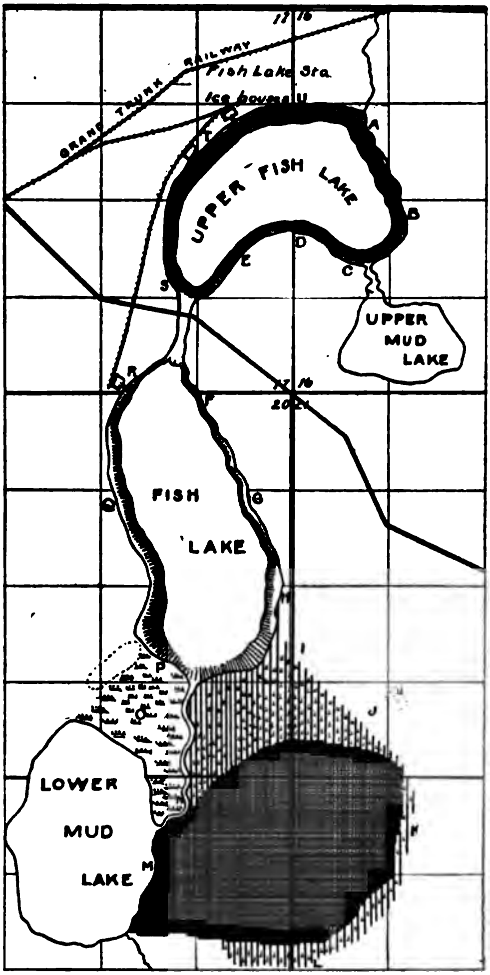


Fig. 67. Map of Fish and Mud Lakes, Laporte County, Ind.

the latter usually only a foot or two in thickness, but in a few places running up to five or six feet. The quality of the marl in all parts of this deposit appeared to be excellent.

The tests showed that this deposit has an area of at least 100 acres of bare dry marl, 10 feet or more thick; probably as much more un-

der less than two feet of muck or in less than 10 feet of water, and an indefinite but probably still larger area of marl existing beneath deep water, under less workable conditions. This is perhaps the closest workable deposit to Chicago and lies adjacent to two good railways, so that its location can hardly be excelled.

STARKE COUNTY.

References.—

1859.—Richard Owen, Geol. Reconn. of Ind., p. 210.

1885.—W. H. Thompson, Fifteenth Ann. Rep. Ind. Dept. Geol. & Nat. Hist., p. 221.

1897.—W. S. Blatchley, Twenty-second Ann. Rep. Ind. Dept. Geol. & Nat. Res., p. 124.

1899.—Frank Leverett, Water Supply and Irrigation Papers, U. S. Geol. Surv., No. 21, p. 39.

Starke County lies in the second tier of counties south of Michigan, and in the third east of Illinois. Its eastern border is 18 miles and its southern border 24 miles in length. Nine miles west of its northeastern corner the Kankakee River intervenes between it and Laporte County, and, flowing southwesterly, forms the remainder of the northern and all but five miles of the western boundary. Yellow River, flowing west through the center of the county, and Bogus River and Pine Creek, north through the southwestern fourth, empty into the Kankakee. The township of North Bend, in the southeastern corner of the county, is drained by several small streams flowing southerly into the Tippecanoe River, which, making a bend to the north, cuts through two sections on the southern line of the township and then leaves the county.

The county is well supplied with railways, four passing entirely across it, while one, the Pan Handle Division of the Pennsylvania System, cuts its southwestern corner. Those crossing it from east to west are the Pittsburgh, Fort Wayne & Chicago across the northern third; the New York, Chicago & St. Louis (Nickel Plate) across the center, and the Chicago & Erie across the southern third. The Indiana, Illinois & Iowa ("Three I") enters the extreme southwestern corner of the county and leaves the northeastern, thus cutting diagonally its full length.

The county has an area of 314 square miles, the surface of which is diversified by marsh, wet prairie, dry prairie and sand ridge, the latter predominating. More than half the area is covered to a depth of

two to 15 feet by the fine grained buff sand so characteristic of all the region adjacent to the Kankakee on the south. Experience has proven that this sandy soil, if properly cultivated, will produce excellent melons, cucumbers, sugar beets, berries, grapes, etc. Where ploughed deep and fertilized it also yields good crops of corn, oats and potatoes. Within the past ten years colonies of frugal, industrious Germans and Swedes have bought at a low price large areas of this once despised land and are making a good living from it. They utilize all fertilizers produced on the farm; they haul muck from the lowlands and mix it with the sand; they plough deeply each season; and by these means and others are proving the land of far greater productive power than it was ever believed to be.

Many thousand acres of the marsh land in the northern half of the county have been recently drained, and where a few years ago the waters were waist deep the year round bountiful crops of corn are now produced. That the county is rapidly coming to the front agriculturally is proven by the growth of Knox, the county seat, where a number of fine business blocks have been erected since 1897, and where a $90,000 court house was finished in 1898.

Not an outcrop of rock occurs in the county. The only bores known to have pierced the thick mantle of drift are at Knox and North Judson, in both of which stratified rock was found about 200 feet below the surface.

The elevation in feet above tide of the principal railway stations in the county is as follows: Aldine, 710; Davis, 681; Grovertown, 715; Hamlet, 695; Jackson, 717; Knox, 710 to 716; North Judson, 695 to 700; Ober, 741; Ora, 721.

With one exception the lakes of the county are small and of little note. Bass Lake, formerly known as Cedar Lake, is, however, one of the largest and best known fishing resorts of the State. It is fully described on subsequent pages. The English Lake of the older maps was but an enlargement of the Kankakee River. Much of its former bed is now annually producing immense crops of corn.

KOONTZ LAKE.

Not a Workable Deposit.

This lake lies in sections 1 and 12 (34 north, 1 west), Oregon Township. It is a shallow body of water covering 200 or more acres and is largely artificial. All the shallow water area around the shores was tested, but only hard bottom was found, except in a few places where beds of muck had accumulated. Many aquatic plants abound in the lake, and as a result the fishing is excellent.

EAGLE LAKE.

NOT A WORKABLE DEPOSIT.

Eagle Lake lies in the northwest quarter of section 13 (33 north, 1 west), Washington Township. Its area has been recently reduced one-half or more by draining. At the time of our visit, in May, 1900, the water covered about 70 acres, and there were extensive marsh meadows on the east and west shores. The north and south shores slope gradually upward into sandy, cultivated fields or woodland. The outlet, Eagle Creek, leaves the west end and flows almost due west into Yellow River. The lake is nowhere more than 18 feet in depth, while much of its area is less than five feet, and bids fair to soon become extinct, as the decay of the abundant water vegetation is rapidly adding to the already extensive beds of muck. Numerous large examples of the bivalve shell, *Anodonta grandis* Say, were found in the muck beds of the lake. The univalves, *Campeloma subsolidum* Anthony and *Helisoma trivolvis* (Say), were also common. The only turtles noted were the stink-pot *Aromochelys odoratus* (Lat.), and the lady turtle, *Chrysemys marginata* (Agas.), which were frequent, especially the last named. A school of carp of large size were routed out of a pool covered with spatterdock on the east end, and made the water boil in their frantic efforts to escape.

MARL.—The only deposit of marl of any size in and about Eagle Lake is in the marsh at the west end. This marsh comprises about 20 acres, and in several bores near the south side the marl was 18+ feet in thickness. It decreases in thickness toward the north and west and becomes overlain with two to four feet of muck. The marsh of 80 or more acres on the east and northeast borders of the lake is wholly of muck, or, if the marl be present, it is more than 16 feet below the surface. In the lake itself, several tests along the north and west shores showed marl ranging from 12 to 15 feet in thickness, but over most of its area muck beds, whose bottom could not be reached, occur. The marl found is of excellent quality, but its quantity is altogether too small for utilization in cement manufacture. It might, however, be used to advantage as a fertilizer on some of the surrounding lands, or for some of the other purposes mentioned on a previous page.

ROUND LAKE.

Not a Workable Deposit.

This is a small and nearly circular lake lying in the east half of section 8 (32 north, 2 west), California Township. Its area is about 120 acres. The water is, for the most part, quite deep, the only shallow area of any size lying along the north shore. The lake abounds in plant life, pondweeds *(Potamogeton)* and millfoils *(Myriophyllum)*, being especially common. The banks of the lake are everywhere low and, except on the north, marshy.

Marl.—The shallow water on the north side was tested in a number of places, but only sand and muck were found. A large area of marsh adjacent to the lake on the southeast was reported to be underlain with marl, but tests showed muck only to a thickness of 16+ feet.

NORTH JUDSON DEPOSIT.

Workable.

This, the only workable bed of marl found in Starke County, is wholly a marsh deposit, lying in sections 10 and 15 (32 north, 4 west), Railroad Township, about three and a half miles west of North

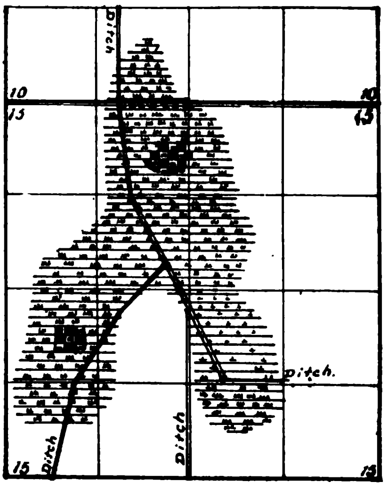


Fig. 68. Map of Marsh Deposit West of North Judson, Starke County, Ind.

Judson. The deposit occupies the basin of an extinct lake. Thirty years ago the lake had become replaced by a marsh over which duck hunters and muskrat trappers hunted and trapped with great success.

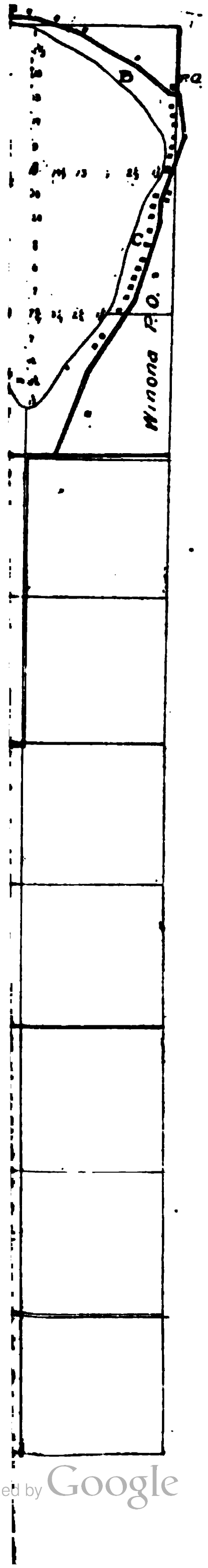
Now part of it is cultivated in corn and the remainder furnishes large and excellent crops of hay. The marl is everywhere overlain with muck, except in one or two places, where it forms the surface. The muck varies in thickness from one to five feet, averaging about two and a half feet. The center of the deposit is two miles from the Chicago and Erie Railway; one and a half miles from the "Three I" Railway, and three miles from the Pan Handle Division of the Pennsylvania Railway. The surrounding country is quite level, so that switches from any one or all of these lines could be constructed at small expense. The most of the land containing the deposit belongs to Jacob Keller of North Judson and F. M. Trissal, 204 Dearborn street, Chicago.

But about 15 acres of the deposit lies north of the east and west wagon road between sections 10 and 15, the remainder being in section 15. In making the tests, 86 in number, over this tract, a hole was dug through the muck to the top of the stratum of marl, and accurate measurements both of the muck and the marl were taken. The 86 bores, made with a 16-foot auger, were put down from 10 to 20 rods apart. They passed through a total thickness of 519 feet of marl, thus showing the average thickness of the bed to be a little more than six feet. These tests include three in which no marl at all was found, and seven where the bottom of the marl could not be reached with the auger. More bores proportionally were put down in the poorer or thinner areas than in the thicker ones, so that the average thickness is above, rather than below, six feet.

A careful estimate of the amount of marl found on the different 40-acre tracts is as follows:

Southeast quarter of southwest quarter of section 10..	15 acres.
Northeast quarter of northwest quarter of section 15..	30 acres.
Northwest quarter of northeast quarter of section 15..	10 acres.
Southwest quarter of northeast quarter of section 15..	20 acres.
Southeast quarter of northwest quarter of section 15..	35 acres.
Southwest quarter of northwest quarter of section 15..	15 acres.
Northwest quarter of southwest quarter of section 15..	30 acres.
Southwest quarter of southwest quarter of section 15..	15 acres.
Northeast quarter of southwest quarter of section 15..	10 acres.
Northwest quarter of southeast quarter of section 15..	25 acres.
Southwest quarter of southeast quarter of section 15..	15 acres.
Total	220 acres.

The best and thickest portions of the deposit occur in the northwest quarter of the southeast quarter of section 15, and the northwest quarter of the southwest quarter of section 15. In the first


Winona P. O.

named tract the top of much of the marl is within six to 10 inches of the surface and the bed is five and a half feet thick. In the second 40 mentioned a fine wire grass, characteristic of marshes containing thick deposits of marl, covered most of the surface. The marl ran from seven and a half to 12 feet thick, with muck from six inches to two and one-half feet overlying.

In color the marl of this deposit is darker than that found in the lakes to the eastward, but this is no doubt due largely, if not wholly, to the seepage from the overlying muck. An analysis of an average sample made by Dr. Noyes, showed the percentage of its constituents to be as follows:

Calcium carbonate ($CaCO_3$)	89.92
Magnesium carbonate ($MgCO_3$)	2.46
Alumina (Al_2O_3)	.45
Ferric oxide (Fe_2O_3)	.74
Insoluble inorganic matter	2.06
Organic matter	4.51
Total	100.14

The large percentage of organic matter shows the presence of the seepage above mentioned. This, however, will burn out in the kiln and is, therefore, harmless. An analysis of a picked sample made for Mr. Keller, by the chemist of the Sandusky (Ohio) Portland Cement Works, showed 90.57 per cent. calcium carbonate and 2.36 of magnesia.

Besides the tract above mentioned, another of 40 or more acres lies about a mile to the eastward in the southwest quarter of the southwest quarter of section 11 and the northwest quarter of the northwest quarter of section 14, on both sides of the road running east and west. The thickness of both muck and marl is here practically the same as that in the Keller—Trissal deposit. Other beds of minor size are said to occur in the same township between these and the Kankakee River.

BASS LAKE.

Not a Workable Deposit.

This lake ranks fourth in size among those found in Indiana; its water area comprising 2.23 square miles. It lies about six miles south of Knox and covers parts of sections 7 and 18 (32 north, 1 west), North Bend Township, and sections 12, 13, 14, 23 and 24 (32 north,

2 west), California Township. The extreme length from northeast to southwest is just about three miles. The northern or longer lobe averages about three-quarters of a mile in width, while the southern basin is a little over a mile wide. These two lobes are separated by long sandy bars which extend out from Cedar and Gull points. Over the bars the water in many places is less than two feet deep. A narrow channel of deeper water intervenes between the ends of the sand spits.

The lake occupies a shallow basin on top of a ridge, the natural surface drainage being all away from its area. The fall from its water level to that of the water in the Tippecanoe River, five miles southeast, is 15 feet. It has at present no outlet or natural inlet. Two artificial ditches drain into it from the marsh land on the east. Its overflow formerly found its way through the marshes at the southwest in a northwesterly direction to the Kankakee River. A portion of the old outlet is now a shallow water marsh, filled with spatterdock, rushes and cat-tail flags. It was formerly an arm or bay of the lake, but has been separated from the main body of water by the levee or fill constructed for a roadway along the northwest shore of the south basin. For a number of years there has been little or no overflow, and the waters of the lake seem to be slowly receding. It is fed almost wholly by subaqueous springs and by the waters of flowing wells, a number of which occur on the north and east shores of the northern lobe. These wells range from 20 to 80 feet in depth. They pass through two to 10 feet of sand, then through a hard-pan clay into a stratum of gravel in which the water is found. More than half of the water area is less than seven feet in depth and fully one-third is less than five feet. Of 516 soundings made by the U. S. Fish Commission in the summer of 1900, 307 showed less than seven feet of water, while 200 showed less than five feet. The average depth found by the 516 soundings was 8.7 feet, while the maximum depth was 32 feet at a point one-third of the way across the lake, north of Cranberry Point. The map will show additional details ascertained by the soundings made.

The greater part of the shore line of Bass Lake is low and marshy. This is especially true of the west half of the south shore, almost the entire west shore, and the west third of the north shore. Between (A) and Winona P. O. at (B), on the accompanying map, the banks at the water margin are low and sandy, but slope up gradually to a height of 10 or more feet, thus furnishing excellent sites for cottages, a number of which have been erected. From (B) to (C) the banks rise more abruptly 15 to 20 feet, and this stretch is also

occupied by a number of cottages. Between (C) and (D) the immediate shore is mostly low and marshy. On Cranberry Point there is higher ground and a fine grove, which is the resort of numerous picnic and fishing parties. South of (D) as far as (E) the banks are mostly high and wooded, but as yet few cottages have been erected. The remainder of the shore, with the exception of a stretch of high ground at Lake Park Station is, for the most part, low and flat. On Cedar Point a large hotel has been built on rather low ground. The north and east shores about Winona P. O. furnish by far the better quarters for summer visitors. If by draining the lake were to be lowered two feet, as has been attempted several times, it would render bare extensive tracts of muck and sand bordering all the shores and destroy much of the charm and healthful surroundings of what is now a beautiful though shallow sheet of water.

At Lake Park Station are several large ice houses belonging to the Knickerbocker Ice Co., of Chicago. A switch connects these with the Chicago & Erie Railway at Bass Lake Station, two miles south. Over this switch a regular train runs daily during the tourist season, and connects with steamers which land passengers at the end of long piers on various sides of the lake. A hack from Winona also connects with all trains at Bass Lake Station.

The bottom of the lake is, for the most part, sand or blue, sticky clay. In the bay east of Cranberry Point there are extensive muck beds. Muck also occurs in quantity beneath a strip 200 feet or more wide, along the west shore between (A) and (F). These muck deposits contain a luxuriant growth of aquatic vegetation. In June the waters of the lake are said to contain vast quantities of a green sediment—probably unicellular plants. When these are present the fishing is poor. The sandy and clay bottoms of the shallow water produce also their characteristic water-plants, so that the lake flora is a very rich one, and worthy of extended study. During the few days spent on and about the lake in May and July, 1900, the following species were noted or collected:

A Partial List of the Plants Known to Occur in Bass Lake or on Its Mucky Margins.*

Juniperus virginiana L. Red Cedar.

Formerly grew in abundance on Cedar Point, where scattering examples still exist. Large cedar logs are occasionally uncovered in the marsh just to the west.

*Mr. H. Walton Clark, of Fort Wayne, kindly identified a number of the pondweeds and other strictly aquatic forms.

Typha latifolia L. Broad-leaved Cat-tail.

Abundant in the marsh at the northwest corner, also in the old bay west of the south basin.

Potamogeton natans L. Common Floating Pondweed.

One of the most common pondweeds in the State. Occurs abundantly in the lake in two to six-foot water.

Potamogeton amplifolius Tuckerm. Large-leaved Pondweed.

Common in three to eight-foot water in the bay north of Cedar Point. Its leaves are larger and more noticeable than those of any other.

Potamogeton lonchitis Tuckerm. Long-leaved Pondweed.

Frequent in water up to 10 feet in depth. The leaves long and slender.

Potamogeton heterophyllus Schreb. Diverse-leaved Pondweed.

Frequent in water less than five feet in depth. The foliage varies exceedingly, the submerged leaves usually lanceolate or linear; the floating ones narrowly ovate.

Potamogeton prælongus Wulf. White-stemmed Pondweed.

Not common. The stem is white and very long and branching, the leaves bright green. Roots at the bottom of eight to 14-foot water, and fruits just at the surface in June or July. It usually withdraws the head of the fruit beneath the water after fertilization has taken place.

Potamogeton pusillus L. Small Pondweed.

A short, narrow-leaved species, growing in shallow water with sandy or mud bottom. Quite common along the north and east shores in two to four-foot water.

Potamogeton pectinatus L. Fennel-leaved Pondweed.

Stem slender, filiform, branching; leaves very narrow linear, in tufts or interrupted masses. Most common in four to eight-foot water. A handsome and easily distinguished species.

Potamogeton friesii Ruprecht.

Found in the bays with muck bottoms. Leaves linear, about two inches in length. Fruit similar to that of *P. pusillus* L., but with a recurved style, a shallow pit on each side, and with the apex of the embryo pointing toward the basal end. Not before recorded from the State except from Maxinkuckee by Dr. Scovell in the present volume, though it occurs in a number of the other lakes.

Nais flexilis (Willd.) Rost. and Schmidt.
Quite common in six to 20-foot water.

Philotria canadensis (Michx.). Water-weed; Ditch Moss.
Abundant in much of the water less than five feet in depth. Varies much in the character of the foliage. Blossoms in June and July. The staminate (male) flowers break off and float free on the surface where they open and set free the pollen, thus enabling it to come in contact with the stigmas of the pistillate flowers which have been raised slightly above the surface by the lengthening of the calyx tube, the latter varying in length according to the depth of the water.

Vallisneria spiralis L. Tape-grass; Eel-grass.
Quite common in the bays and along the margins wherever muck occurs. Grows in water between two and 10 feet in depth. A plant of peculiar habits, fertilized much as in the preceding; the long thread-like scapes coiling spirally after fertilization and drawing the fruit beneath the water to ripen.

Sagittaria latifolia Willd Broad-leaved Arrow-head.
Common along the shore in mucky places, and in ditches.

Sagittaria rigida Pursh. Stiff-stemmed Arrow-head.
With the preceding but much less common.

Sagittaria graminea Michx. Grass-leaved Arrow-head.
Occurs frequently in mucky places where the water is less than a foot in depth.

Zizania aquatica L. Wild Rice.
Frequent in the marshy area on the west side of the south basin, also in shallow water in several places along the west shore. The stems were many of them 10 to 12 feet in height, and the leaves often a yard long.

Eleocharis mutata (L.). Quadrangular Spike-rush.
This pretty and rather scarce rush grows in numbers in the shallow water along the north shore of the south basin.

Scirpus americanus Pers. Chairmaker's Rush.
Abundant in many places along the shores, in water one to four feet in depth.

Scirpus lacustris L. Great Bulrush.
Abundant, growing on sandy bottom in water up to eight feet deep.

Lemna trisulca L. Ivy leaved Duckweed.

Common on the surface over muck beds. In late summer a large number of the fronds are connected into one sheet or mass.

Lemna minor L Lesser Duckweed.

Abundant with the above.

Eriocaulon septangulare With Seven-angled Pipewort.

Common in the bay east of Cranberry Point, also in the shallow water near the northwest shore. Varies much, according to the depth of water, in the length of the scape.

Pontederia cordata L. Pickerel-weed.

Frequent in company with arrow-head and spatterdock about the margins of the muck areas.

Betula nigra L. River Birch; Red Birch.

A number grow in the marsh on the northwest shore of the main basin.

Brasenia peltata Pursh. Water-shield.

Common in the bays which contain muck. Notable on account of its shield-shaped floating leaves which are borne on long mucilage-coated stems.

Nymphæa advena Soland. Large Yellow Pond Lily.

Abundant in muck beds in water a foot or less deep.

Castalia odorata (Dryand). White Water Lily.

Less common than the yellow lily. Grows in water a foot or two deeper.

Ceratophyllum demersum L Hornwort.

Abundant. Wholly submerged at the bottom of water 6 to 20 feet in depth, forming thick masses or beds which serve as shelter and feeding places for many fishes and other aquatic animal forms.

Caltha palustris L. Marsh Marigold.

Several large patches occur in the marshes at the northwest corner of the north basin.

Ribes floridum L' Her. Wild Black Currant.

A number of bunches occur in the marsh above mentioned. In flower May 8, 1900.

Rhus vernix L Poison Elder.

Common in the same marsh. The large compound leaves are often two feet in length. More poisonous than the common poison ivy, the juice or exhalation of its leaves causing small

white blisters everywhere on the surface of the exposed skin. An infallible remedy is a saturated alcoholic solution of sugar of lead several times applied to the skin as soon as the blisters appear. A water solution is of little if any value.

Triadenum virginicum L. Marsh St. John's-wort.

Found in the same marsh as the last three; not common.

Decodon verticillatus (L.). Swamp Loose strife.

Borders of the muck marshes along the west shore; abundant. Its long, recurved stems bend gracefully over the water's edge and when in blossom the rose purple flowers make it truly a notable and handsome plant.

Hydrocotyle umbellata L. Marsh Pennywort.

In water three to six inches deep or on the sandy margin along the north shore.

Chamædaphne calyculata (L.). Leather-leaf.

Abundant in the bog northwest of the main basin. A low branched shrub, with nearly evergreen, oblong leaves and white bell-shaped flowers, which are in blossom about May 1st. Forms a close cover over the surface of much of the bog area.

Gaultheria procumbens L. Creeping Wintergreen.

This pretty trailing shrub is plentiful in the woods north of the main lake. It is common in wet shaded places about tamarack and pine swamps in Lake, Porter and Laporte counties, and has been found by the writer as far south as the Pine Hills, Montgomery County, where it occurs on the "Devil's Back Bone."

Oxycoccus macrocarpus (Ait). Large Cranberry.

Occurs sparingly in the bog at the northwest corner of the main basin.

Menyanthes trifoliata L. Marsh Bean.

Common about the margins of bogs in different places around the lake shore.

Bidens beckii Torrey. Water Marigold.

Occurs in abundance in different parts of the lake in water between four and 15 feet in depth. A peculiar member of the family Compositæ in that it is strictly aquatic—its long and slender stems bearing at intervals bunches of crowded, capillary, many dissected leaves.

A Partial List of the Mollusca Inhabiting Bass Lake.

No especial search was made for the mollusca inhabiting the lake, only such specimens being taken as came readily to hand. The list is therefore much smaller than that of the corresponding group from Lake Maxinkuckee.

UNIVALVES.

1. Succinea ovalis Gould.

   A number were taken from the stems of rushes and other aquatic plants along the margin of the north basin.

2. Limnophysa palustris Müller.

   Quite common about the margins of the muck beds. Readily distinguished from its allies by the numerous slightly raised reticulating lines and wrinkles. The adults are much larger than either of the next two species.

3. Limnophysa desidiosa Say.

   This and the next species were very abundant on the stems of rushes and other water plants in the shallow water, especially along the north shore.

4. Limnophysa humilis Say.

   With the preceding and probably more abundant.

5. Physa gyrina Say.

   Occurs sparingly along the margins of the muck beds and in the ditches flowing into the lake.

6. Physa heterostropha Say.

   Common in the ditches and in the swamp at the northwest margin.

7. Planorbella campanulata Say

   This very pretty shell is found in company with its larger congener, *H. trivolvis,* in the shallow sandy and muddy marginal waters all around the lake.

8. Helisoma trivolvis Say.

   This, the largest of the discoidal univalves, is very common, not only in Bass Lake, but in most if not all of the lakes of northern Indiana. It frequents the reedy shallow water margins.

9. Gyraulus parvus Say.

This little shell, the smallest of the discoidal group of which it is a member, was quite common on lily pads and stems of pondweeds in the shallow-water bays.

10. Amnicola porata Say.

Several were taken from the stems of aquatic plants. They were in company with the small species of *Limnophysa*.

11. Vivipara contectoides Binney.

One of the most common univalves in the lake. Readily known by the three or four brownish-red revolving bands on the body whorl. Occurs everywhere in shallow water.

12. Vivipara intertexta Say.

Occurs with the last named but less common. The adults are wholly brownish-red in color.

13. Campeloma decisum Say.

A few dead specimens of this mollusk were found along the sandy margins of the north shore. In Maxinkuckee three species of *Campeloma* occur in abundance.

14. Goniobasis livescens Menke.

Very abundant, the young occurring by thousands in the sand at the bottom of the shallow water along the south shore of Cedar Point. The different stages vary much in appearance and the tyro is apt to consider them distinct species.

BIVALVES.

No examples of the genus *Unio* were found in the lake, though six species are known to occur in Lake Maxinkuckee. One reason for their greater numbers there is doubtless the presence of several inflowing streams, as the thick shelled *Unios* are much fonder of flowing water than their more fragile allies, the *Anodontas*. But four species of bivalves were noted. No one of them was common. A careful search of the lake will probably bring to light a number of others.

15. Anodonta grandis Say.

Several living half grown specimens and a number of dead shells of this large bivalve were found on and about the various muck beds.

16. Anodonta salmonia Lea.

This is also a mud-loving form. A number were secured while seining in the channel in front of the hotel on Cedar Point.

17. **Anodonta footiana Lea.**

A number were taken along the north shore. It is a very common mollusk in the Indiana lakes. Frequents for the most part sandy or marl bottom beneath two to five feet of water.

18 **Anodonta fragilis Lam.**

Several specimens were taken with the above. This is its first definite record for the State, though it is said to be common in the lakes of Michigan, New York and Canada.

The Fishes of Bass Lake.

Bass Lake is one of the best and most noted fishing resorts of Indiana. The large amount of aquatic vegetation furnishes much available food for the smaller species, while they in turn are preyed upon by the larger. Many visitors from Chicago, Indianapolis and other smaller cities and towns of northern Indiana and eastern Illinois visit the lake, some of them several times each year. Many of them have cottages on the lake and spend a month or more there, while the hotels are always crowded with guests during the summer season.

The number of species of fish known from Bass Lake is not as large as from Maxinkuckee for two reasons: First. The waters of the latter have been much more thoroughly worked by the members of the U. S. Fish Commission and others in order to determine the species found therein. Second. The numerous inlets entering Lake Maxinkuckee contain several species which often find their way into that lake but which have not yet been found in Bass Lake, as it has no inlets of any size. The following list of species is based upon a collection made by the writer and assistant in Bass Lake on August 8 and 9, 1900, and upon notes taken May 8 to 10, 1900. Mr. Frank Hay furnished much of the data concerning the time and place of spawning and the size to which the food and game fishes grow:

1. **Lepisosteus platostomus Raf Short-nosed Gar.**

Very common; feeds mostly upon minnows and the young of many game fishes, and is therefore hated by all fishermen. In the spawning season, which occurs in May, they swim in schools, and Mr. Hay killed with a shot gun 115 in one day in the shallow water along shore. The females, which are much the larger, reach a length of three feet and a weight of 10 to 12 pounds.

2. **Amia calva L. Dogfish; Mudfish; Bow-fin**

Common. Also rapacious and very harmful to food and game fishes. Reaches a weight of 18 pounds. The flesh is pasty and

generally regarded as worthless but is eaten by some people. The dogfish is a quick and ready biter, is full of pluck, and a large one furnishes much sport before it is landed. It is extremely tenacious of life and will live out of water for a long time. It is sometimes shut in shallow bays which gradually dry up and the fish will be found alive in the slimy mud, after all vestige of water has disappeared. Besides small fishes, its principal food is univalve and bivalve mollusks, insects and insect larvæ, crayfish, shrimps, etc.

3. **Ameiurus natalis** (Le S.). **Yellow Cat.**

The largest catfish of the lake and the one most commonly caught on hooks. It will bite almost anything in the way of fish or flesh and can be caught from March to December in from six to 25-foot water, especially that with muck bottom.

4. **Ameiurus nebulosus** (Le S.). **Common Bull-head.**

Probably more common than the last, but less often caught. Reaches a weight of 1½ pounds. Feeds on everything that usually serves as food for fishes, and many other things besides. The following, by one of the former editors of the Milwaukee Sun, well illustrates the habits of this well-known fish: "To catch the Bull-head it is not necessary to tempt his appetite with porter-house steak, or to display an expensive lot of fishing tackle. A pin hook, a piece of liver and a cistern pole is all the capital required to catch a Bull-head. He lies upon the bottom of a stream or pond in the mud, thinking. There is no fish that does more thinking or has a better head for grasping great questions, or chunks of liver, than the Bull-head. His brain is large, his heart beats for humanity, and if he can't get liver, a piece of tin tomato can will make a meal for him. It is an interesting study to watch a boy catch a Bull-head. The boy knows where the Bull-head congregates, and when he throws in his hook it is dollars to buttons that 'in the near future' he will get a bite. The Bull-head is democratic in all its instincts. If the boy's shirt is sleeveless, his hat crownless, and his pantaloons a bottomless pit, the Bull-head will bite just as well as though the boy is dressed in purple and fine linen, with knee breeches and plaid stockings. The Bull-head seems to be dozing on the muddy bottom, and a stranger would say that he would not bite. But wait. There is a movement of his continuation and his cow-catcher moves gently toward the piece of liver. He does not wait to smell of it, and canvass in his mind whether the liver is fresh. It makes no difference to him. He argues that here is

a family out of meat. 'My country calls and I must go,' says the Bull-head to himself, and he opens his mouth and the liver disappears.

"There is one drawback to the Bull-head, and that is his horns. We doubt if a boy ever descended into the patent insides of a Bull-head to mine for limerick hooks, that did not, before the work was done, run a horn into his vital parts. But the boy seems to expect it and the Bull-head enjoys it. We have seen a Bull-head lie on the bank and become dry and to all appearances dead to all that was going on, and when a boy sat down on him and got a horn in his elbow, and yelled murder, the Bull-head would grin from ear to ear, and wag his tail as though applauding for an *encore*."

5. **Catostomus nigricans Le S. Hog Sucker.**

Not seen by the writer, but Mr. Hay reports a sucker reaching a weight of half a pound which, from his description, is probably this species.

6. **Erimyzon sucetta oblongus (Mitch.). Chub Sucker; Sweet Sucker.**

Common, especially so in the channel in front of Brabrook's hotel, where many young were taken August 9th. Readily known by the entire absence of the lateral line. Rarely reaches a length of a foot, but the flesh is soft and of little food value. Lives in pools with muck bottom and feeds upon the algæ, insect larvæ, decaying plants and similar vegetable matter. The young are rather pretty, the black band on the sides being very distinct and some of the fins usually tinged with reddish or orange.

7. **Cyprinus carpio L. Carp.**

Common in the lake, where it was probably introduced, as it could not have entered by overflow waters. Seldom used for food by the residents near the lake. One weighing 13 pounds was speared on May 9th, and specimens weighing 18 to 20 pounds are often taken. It is regarded as harmful to our native fish and is destroyed by sportsmen whenever possible.

8. **Campostoma anomalum (Raf.). Stone-roller; Stone-lugger.**

A few examples of this interesting minnow were taken in the ditch leading into the lake between Cranberry and Gull points.

9. **Pimephales notatus (Raf.). Blunt-nosed Minnow.**

Abundant. This and the next species are the most common forms used for bait. Known by the blunt, decurved snout, de-

pressed top of head, and dark spot on front rays of dorsal fin. Old males in spring have numerous tubercles on the head.

10. NOTROPIS HETERODON (Cope). Variable-toothed Minnow.
Quite common in all the shallow portions of the lake, where it doubtless forms much of the food of the larger game fishes. Distinguished from the above by the incomplete lateral line, and the more pointed head.

11. NOTROPIS WHIPPLII Girard. Silver-fin.
A common form, ranging in width between the last named and the next, and also distinguished by the dark blotch on the last rays of the dorsal fin. In the breeding season one of the most handsome of minnows.

12. NOTROPIS CORNUTUS (Mitch.). Silver-side; Shiner; Rot-gut.
Apparently much more common in Bass Lake than in Maxinkuckee. Forms much of the food of the black bass and other game fishes. The exposed portion of the scales on the sides are much higher than long. The body cavity is lined with black. The flesh is soft and spoils very soon after death, whence the common name of Rot-gut.

13. ABRAMIS CRYSOLEUCAS (Mitch.). Golden Shiner; Bream.
Very common in the bays with muck bottoms, especially so in the one in front of Brabrook's. Resembles the shiner, but distinguished by the long anal fin which has a sharp ridge or carina in front of it.

14. UMBRA LIMI (Kirt.). Mud Minnow.
Scarce. One specimen was taken with a dip net in May from the marsh at the northwest corner of the lake, and another in July from the main ditch on the east side. Reaches a length of only four inches. It is the only small fish found in Indiana which has a rounded caudal fin with black bar at the base. It is notable for the length of time which it can survive in mud after the water has evaporated, and it is said that living specimens are often ploughed up in the bed of a dried up pond or swamp.

15. LUCIUS VERMICULATUS (Le S.). Little Pickerel; Grass Pike
Common in shallow pools about the weedy margins. Reaches a length of a foot and a weight of a pound, or a little more. Like its larger relatives it is very voracious and sometimes pays the penalty of its life in attempting to swallow something too large

for its gullet. A dead specimen was taken at the margin of the lake in May which was 11 inches long. It had attempted to swallow a blue-gill, *Lepomis pallidus* (Mitch.) four inches long and three inches wide, but the size and spines of the latter interfered and the pike was choked to death, the throat being badly torn.

16. Lucius lucius (Linn.). **Common Pike; Pickerel.**
Formerly common but now rarely seen. One, taken in the lake in May, 1899, was 31 inches long and weighed 10 pounds. The largest one known to have been taken in the lake in the past weighed 28 pounds. They frequent, for the most part, six to 20-foot water, near the edges of the beds of hornwort and other plants.

17. **Fundulus diaphanus menona (Jor. and Cope). Barred Killifish; Spring Minnow.**
Abundant in the shallow water over sandy bottom. Full grown specimens are four inches long. Known by the 12 to 16 dark cross bars on the sides. Feeds on the smaller mollusks, larvæ of insects, etc.

18. **Fundulus dispar (Agassiz). Top Minnow.**
Frequent. Thicker and shorter than the preceding. A pale spot on top of the head, and about 10 narrow lengthwise bars on the sides. The males have also about nine line-like cross bars. Frequents for the most part the bays and inlets, where it is seen in small schools swimming close to the surface.

19. **Labidesthes sicculus (Cope). Skipjack; Brook Silverside.**
Abundant. A small and graceful species which is usually seen in schools close to the surface. It often throws itself above the water, whence its common name. Known by its slender translucent body, two dorsal fins and bright silvery stripe along the sides. Feeds on minute crustacea, mollusks, etc.

20. **Pomoxis sparoides (Lacépède). Calico Bass; Grass Bass; Croppie.**
Common. Much more so than in Lake Maxinkuckee. Frequents six to 25-foot water. Reaches a weight of 1½ pounds. Nests in the sand in six to eight-foot water. A handsome and valuable food fish, which takes the hook best in April, May and October.

21. **Ambloplites rupestris (Raf.). Goggle-eye; Red-eye; Black Perch.**
Common. Frequents six to 12-foot water along the edges of immersed banks of vegetation. Spawns in May in sand at the

bottom of four to six-foot water. According to Dr. S. A. Forbes, the young, up to an inch in length, live principally on minute crustaceans; beyond this size up to three inches, on aquatic insects and their larvæ, while the larger specimens feed on minnows, insects and crayfish.

22. CHÆNOBRYTTUS GULOSUS (Cuv. and Val.). **War-mouth; Indian Fish.**

Abundant among the weeds at the bottom of six to 12-foot water, it and the blue-gills being the most common species caught while still-fishing. Mr. Hay reports that it spawns in the mud below three to five-foot water. Its food at different ages is the same as that of the goggle-eye. It is, however, more gamy. Both are excellent pan fishes.

23. APOMOTIS CYANELLUS (Raf.) **Green Sunfish; Rock Bass**

Frequent, especially in the bays with muck bottom. Known by its oblong body, large mouth, low spines and narrow wavy stripes of blue on the cheeks. A handsome species, which reaches a weight of little over half a pound.

24. LEPOMIS MEGALOTIS (Raf.). **Long-eared Sunfish.**

Frequent, especially in two to four-foot water, among the weeds growing from sandy bottom. Readily distinguished by its brilliant colors and long black ear flap margined with paler. Reaches a length of six or eight inches. Years are spent by these long-eared sunfish in a dreamy sort of existence, their energies quickened by the vernal season and growing duller on the approach of winter. Excepting the times when they are tempted by a wriggling worm on some boy's hook, theirs is a life exempt from danger. A kingfisher glancing down from his perch on a bent sycamore limb may, at times, discern them and lessen their ranks, but, methinks, the chub minnows, with fewer spines in their dorsal fins, are more agreeable to the kingfisher's palate. With all the tints of the rainbow gleaming from their sides they move to and fro, the brilliant rulers of the quiet pools in which they abide.

25. LEPOMIS PALLIDUS (Mitch.) **Blue-gill; Blue Sunfish.**

Common in schools at the bottom of six to 25-foot water. Reaches a weight of three-quarters of a pound. Spawn in shallow circular nests in the sand, which they scoop out with the tail, the nests being beneath three to four-foot water. A valuable food fish and one of the gamiest of the sunfishes.

26. EUPOMOTIS EURYORUS (McKay). Broad-eared Sunfish.

Scarce. Three specimens were taken in June, 1900, by Mr. Hay, which were eight inches long by five wide. It was first thought they were the Chain-sided sunfish, *Lepomis machrochirus* (Raf.), but a more careful examination proved them otherwise. They were caught while still-fishing among a school of blue gills. Known from the blue gill, which it most closely resembles, by the bluntly conic pharyngeal teeth and by the ear flap being margined with reddish orange. Taken before in Indiana only in Cedar and Shriner lakes, Whitley County, and in Lake Maxinkuckee.

27. EUPOMOTIS GIBBOSUS (Linn.). Common Sunfish; Pumpkin Seed.

Abundant. Known by its deep body with strongly curved outline, short rounded ear flap, small mouth, high dorsal spines and brilliant coloration. Reaches a weight of one-half pound or more. Feeds on insects, small crustaceans and, especially, univalve mollusks. The eggs are laid in nests in the mud, sand and gravel and are guarded carefully by the male. The "sunny," as it is sometimes called, bites with vigor at almost any kind of bait small enough for it to swallow.

28. MICROPTERUS SALMOIDES (Lacépède). Large-mouthed Black Bass.

Common; reaches a weight of eight pounds. Frequents three to 12-foot water. Spawns in sandy places beneath two to three-foot water. The most noted game fish in the State and, according to Mr. Hay, the only bass occurring in Bass Lake.

29. PERCA FLAVESCENS (Mitch.). Yellow Perch; Ringed Perch.

Abundant but mostly of small size. Specimens weighing one and one-half pounds have, however, been taken. Occurs in water of all depths, the larger in the deeper water. Will bite almost any kind of bait. "The perch is a tough and heedless fish, biting from impulse, without nibbling and from impulse refraining to bite, and sculling indifferently past. It is a true fish, such as the angler loves to put into his basket or hang on the top of his willow twig, on shady afternoons, along the banks of the streams. So many unquestionable fish he counts and so many shiners which he counts, and then throws away."—*Thoreau.*

30. BOLESOMA NIGRUM (Raf.). Johnny Darter; Tessellated Darter.

Abundant. Reaches a length of only two and a half inches; occurs everywhere in shallow water with sandy bottom. The only darter taken in the lake, though three or four others doubt-

less dwell therein. The "Johnny" lurks on the bottom, moving when disturbed with great rapidity for a short distance, then resuming its former quiet position. "Crouching cat-like before a snail shell it will snap off the horns which the unlucky owner pushes timidly out, or at times seizes the animal by the head and dashes the shell against a pebble or larger stone until it pulls the body out or breaks the shell."

Turtles of Bass Lake.

More species of turtles have been taken in and about Bass Lake than about any other lake in the State. During our visits in May and July, the following species were noted:

1. Aspidonectes spinifer (Le S.). Common Soft-shelled Turtle.
   Frequently seen swimming gracefully close to the bottom and resting among the lily pads in the coves and bays. This turtle is much relished as food, and several turtle catchers from Chicago visit the lake each season and set nets for it and the next species.

2. Chelydra serpentina (L.). Common Snapping Turtle.
   The largest turtle in the lake—very common among the vegetation growing from the muck beds.

3. Aromochelys odoratus (Latreille). Musk Turtle; Stink-pot.
   Next to *Chrysemys marginata* the most common turtle in the lake. It was noted for the most part in the vicinity of the sedges and rushes along the sandy shores in water up to a foot or two in depth. One specimen was taken in May which had a mollusk, *Helisoma trivolvis* (Say), in its mouth.

4. Malaclemmys geographicus (Le S.). Map Turtle.
   Much less common in Bass Lake than in Maxinkuckee. Frequents the shallow water in the vicinity of the shore, where it feeds principally upon mollusks, especially the thin-shelled species of *Limnophysa*, which occur in abundance upon the rushes and other vegetation.

5. Kinosternon pennsylvanicum (Bosc). Mud Turtle.
   A number of specimens of this small box-turtle were taken from the shallow water along the north shore. It is a uniform dusky brown in color, and the lobes of the plastron are nearly equal in size and hinged so that they are movable at will. The animal can, therefore, when threatened with danger, retire

wholly within the shell in a manner similar to the common dry land box-turtle, *Cistudo carolina* (L.). The food of the mud turtle consists of small fish, insects, mollusks, leeches, and other small water and mud inhabiting animals. This species is rather scarce in Indiana, having been recorded heretofore only from Knox and Vigo counties.

6 **Pseudemys elegans (Wied.). Elegant Terrapin.**

As the specific name implies, this is one of the most handsome of the fresh water turtles. In Bass Lake it is quite frequent and reaches a large size, two which were captured by Mr. Hay, being respectively 10 and 11 inches in length. They were taken after night while moving rapidly along the bottom of the shallow water. It has been reported from no other lake in the State, but has been taken in the Tippecanoe River near Winamac, and in the Wabash at New Harmony; also by the writer in a large pond in Vigo County.

7. **Chrysemys marginata (Agas.). Lady Turtle.**

Abundant, especially in bays and coves among the masses of spatterdock and white water lilies. Here on warm sunny days it may be seen by dozens lying upon any object large enough to bear its weight, basking in the sunlight. When approached it stretches aloft its neck and gazes an instant or two at the intruder, then with a splash tumbles into the water and burrows into the protective mud at the bottom. A few bubbles of marsh gas which it has set free, rising to the surface, usually betray its resting place.

8. **Chelopus guttatus (Schneider). Speckled Tortoise.**

This handsome little turtle was very common in the ditches putting into the lake, and in the marsh area at the extreme northwestern corner. It is found in similar localities all over the northern third of the State.

9. **Emys meleagris (Shaw). Blanding's Tortoise.**

Two specimens, one living, the other dead, of this rather scarce turtle were found in the lagoon or marsh adjoining the western end of the south basin. Mr. Hay has often noted them along the northern margin of the main lake. The yellow spots on the carapace vary much in size and number. Several specimens were also taken from ditches along the roadside about four miles northeast of the lake. It occurs sparingly in similar localities through the lake region of the State.

10. **Cistudo carolina (L.). Common Box Turtle.**

This strictly dry-land species has been frequently noted by Mr. Hay in the sandy upland woods, bordering the lake on the north.

Marl.—Little if any marl occurs in the northern lobe of Bass Lake. A few traces of it were found beneath the muck along the west shore. At a point about 1,500 feet west and 500 feet north of the steamer landing at Winona P. O. a bed of marl three feet thick underlies about 20 acres of seven-foot water.

In the southern basin a small deposit of marl was found, lying northwest of Lake Park Station. It is estimated to cover about 35 acres. The greatest depth found was five feet in four feet of water at 200 to 300 feet from shore. At twice that distance from shore, still in four feet of water, the marl was only three feet thick. The deposit does not appear to run much if any east of the long pier near the ice house, and thence westward a quarter of a mile or less. The assistants on the U. S. Fish Commission, while making soundings, found also a small bed in the northern half of the same basin, but its bounds were not accurately determined. The quality of the marl is not of the best, it being darker than the average and in places more or less mixed with muck or sand.

In the southeast corner of section 11, just west of Bass Lake, marl was found in a large dredged ditch, but proved on examination to have a thickness of only one foot, with five feet of muck overlying.

LAKE COUNTY.

References—

1897.—W. S. Blatchley, Twenty-second Ann. Rep. Dep. Geol. and Nat. Resour. of Indiana, p. 25.

The report above cited contains an extended paper giving in detail the facts relative to the topography and geology of Lake County. To it the reader is referred for the general information which in the present paper it has been customary to give under the county heading. There is but one lake of any size in the county, namely, Cedar Lake, described below.

CEDAR LAKE.

Not a Workable Deposit.

Cedar Lake, or "Lake of the Red Cedars," is located in parts of sections 22, 23, 26, 27, 34 and 35 (34 north, 9 west), on the line be-

tween Center and Hanover townships, about four miles southwest of Crown Point. Its general outline somewhat resembles that of a kidney. Its length is about two and one-eighth miles and its greatest breadth a little more than three-quarters of a mile. Its water area, as computed by Thomas Large,* is at present about 1.17 square miles.

Cedar Lake owes its origin to the irregular deposition of the surrounding drift. On all sides, except the south, it is embraced by wooded ridges of sand or clay, those to the north rising 60 feet above the level of its waters. Between these ridges, on the southern slope of the moraine, a long, low valley was left by the retreating ice sheet. The bottom of this valley was covered with an impervious stratum of clay. In its depression collected the waters of the melting glacier, and the lake resulted. Its waters once covered all the low, marshy land to the southward and overflowed the lowest part of the rim of its basin toward the Kankakee. At that time they covered the present shores as far as the foot of the ridges on the east and north, and were probably 40 feet deep in places. Now they nowhere exceed 20 feet in depth. Within the memory of man they have receded from 50 to 90 feet from the former margins.

The principal cause of this recession was artificial drainage. To reclaim 200 acres of comparatively worthless marsh land—at its southern end— a ditch was cut on its eastern side which lowered the level of the water from eight to 12 feet. This outlet is the present source of Cedar Creek, which flows southward through the town of Lowell and empties into the Singleton ditch.

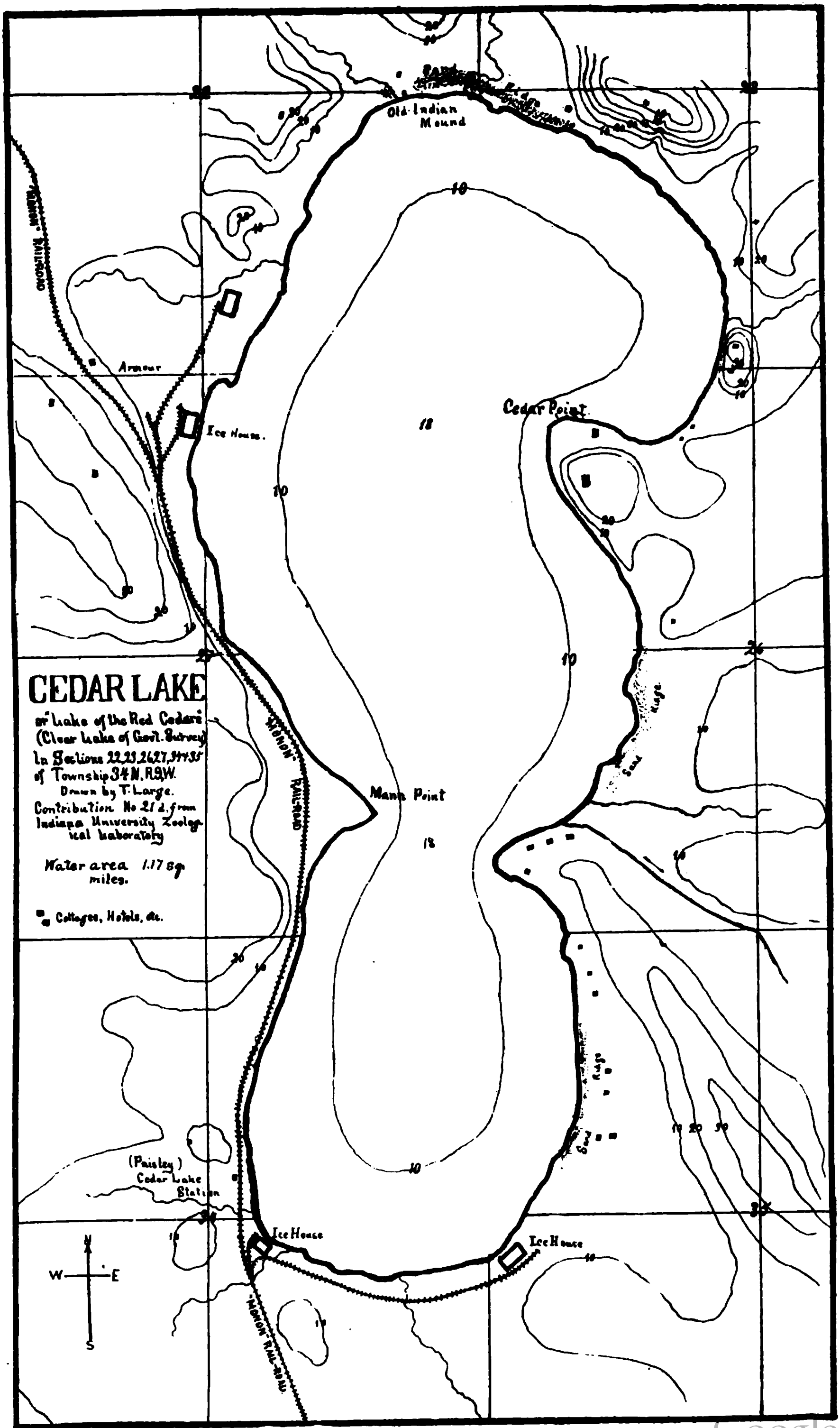
Thick beds of muck and black mud along the southern and western margins produce a luxuriant growth of water vegetation which each year decays and adds to the thickness of the slowly rising bottom. Again, situated as it is so near the crest of the moraine, the area from which the lake draws its supply of water is very limited, being but a few square miles in extent. At present the season's evaporation is, probably, almost as great as the supply. For these causes the area and depth of the lake have for years been slowly diminishing and will continue to diminish until it wholly disappears.

Within the past 10 years many cottages have been erected on the wooded ridges about Cedar Lake. The C., I. & L. (Monon) Railway, which runs along its western border, has possessed itself of the high wooded ridge on that side and has transformed it into a so-called park. Thousands of visitors are each season brought from

*See Proc. Ind. Acad. Sci., 1896, pp. 299–301. The accompanying map of Cedar Lake was also drawn by Mr. Large and published in the Proceedings of the Academy, loc. cit. By permission it is reproduced in this connection.

PLATE 12.

GLIMPSES OF CEDAR LAKE, LAKE COUNTY, INDIANA.



CEDAR LAKE
or Lake of the Red Cedars
(Clear Lake of Govt. Survey)
In Sections 22,23,26,27,34&35
of Township 34 N. R.9.W.
Drawn by T. Large.
Contribution No 21 d. from
Indiana University Zoological laboratory
Water area 1.17 sq. miles.
Cottages, Hotels, &c.
Old Indian Mound
Sand Ridge
Armour
Ice House.
Cedar Point.
Mann Point
Monon Railroad
Monon Rail-Road
Sand Ridge
(Paisley)
Cedar Lake Station
Ice House
Ice House
N
W
E
S

Fig. 70.

Chicago and from the cities to the southward. The quiet beauty and repose which for centuries existed along the margins of the lake have forever disappeared. In their stead have sprung up those artificial surroundings which the ever increasing wants of the Twentieth Century seeker after pleasure demand and eventually secure.

MARL.—No sign of marl was found in this lake. Sand only occurs along the east and west sides, in places running into sandy muck. At the south end the bottom is a stiff, blue clay, with a foot of muck over it. Tests made in the marsh one-quarter of a mile south of the ice houses showed one to four feet of muck over blue mud.

MINOR DEPOSITS OF MARL.

A large number of deposits of marl, not mentioned on the preceding pages, occur in various parts of northern Indiana. They are too small to develop for cement making, but might be utilized for some of the other purposes given in the list of uses. For the most part they occur in marshes and are usually overlain by muck of varying thickness. Information concerning, and samples from, a number of them have been received by this Department, but lack of time forbade a personal investigation of but two or three. Those concerning which we have information deemed worthy of publication are as follows:

NEAR BRIGHTON, LAGRANGE COUNTY.—Mr. Chas. N. Libey, of Brighton, wrote that he had 40 acres of marsh marl and that there was enough adjoining to make, perhaps, 100 acres in all. It had been examined to some extent by parties wishing to purchase marl lands. They reported the bed to run from seven to 25 feet in thickness.

NEAR NAPPANEE, ELKHART COUNTY.—Samples excellent in quality were received from George Meeker. He reports it as outcropping for a distance of one-fourth of a mile or more in the bed of a small creek and then disappearing beneath the muck. At one place there is exposed a bank or face surface of the marl more than four feet in thickness. No tests were reported as to its actual thickness in the bed of the creek. The muck over the marl along the bank is about two feet thick. Mr. Meeker adds: "From the lay of the land I would think there are several hundred acres of this material, but this is only guesswork."

TWELVE MILES NORTHWEST OF SOUTH BEND.—This deposit is in Michigan, just north of the Indiana line, in the northeast quarter

section 16 (18 west, 8 south). It is in a marsh, the bed of an extinct lake, on the land of John Curran, two miles south of the Michigan Division of the "Three I" Railway. There are probably 40 acres underlain by marl which varies between two and 21+ feet in thickness. In places it comes to the surface, but it is mostly overlain with a thick deposit of muck. The marl is of good quality, as is evinced by the following chemical analysis made for Mr. Curran by Prof. Frank S. Kedzie, Agricultural College, Michigan:

Calcium carbonate ($CaCO_3$)	89.63
Magnesium carbonate ($MgCO_3$)	2.12
Iron and aluminum oxides	.62
Insoluble matter (mostly clay)	.42
Organic and undetermined matter (alkalies, etc.)	7.55
Total	100.35

NEAR WELLSBORO, LAPORTE COUNTY.—Mr. Othie Way, of Wellsboro, sent samples of good quality, accompanied by the following information: The deposit is beneath a marsh on his farm, nine miles south of Laporte and less than a mile east of Wellsboro. It covers an area of 55 to 60 acres by the side of the Grand Trunk Railway. Muck running from two to three feet in thickness overlies the marl. The latter is known to be eight feet in thickness in places, but neither its maximum nor average thickness has been determined.

NEAR PATTON, WHITE COUNTY.—A small deposit occurs on the land of A. A. McKain, one-half mile west of Patton, near the C., I. & L. (Monon) Railway. It is less than 10 acres in size, is covered with two feet of muck, and averages six feet in thickness.

NEAR PERU, MIAMI COUNTY.—A deposit of undetermined area occurs four miles southwest of Peru on the land of Milton Shirk. The Wabash Railway runs through this deposit. The marl is of good quality and is known to be over four feet in thickness in a number of places, with two to three feet of earth overlying.

Another marsh deposit overlain by muck occurs just west of the Catholic cemetery and north of the driving park at Peru. It is on the land of Edward Riley and lies alongside the Wabash Railway. It is said to run from nine to 12 feet in thickness and to range in color from almost pure white to dark gray.

NEAR ADAMSBORO, CASS COUNTY.—A deposit of some size occurs near Spring Creek, on the land of Mac. Colgan. It underlies an area of more than 40 acres and is covered with muck or soil to a depth of two to four feet. At one place on the bank of the creek it shows a face of nearly six feet, and in another place more than four feet.

NEAR FOREST, CLINTON COUNTY.—Prof. J. W. Hadley sent in samples of a good quality of marl. He stated that it had been found in three different localities within less than two miles of Forest. The area of the different beds was not determined. They are from two to four feet below the surface and range from 18 inches to 10 feet in thickness.

NEAR BLOOMINGPORT, RANDOLPH COUNTY.—Samples were sent in by C. S. Hunt, who reports that the deposit occurs to quite a depth in the bottom of an old pond of large size. It is overlain by muck, two feet in thickness. Mr. Hunt also states: "I have used the marl as a polish on different metals and find it equal to any polish on the market."

NEAR CLINTON, VERMILLION COUNTY.—An examination of this deposit was made by Mr. J. W. Robb, of Clinton, who reported it to cover about three acres, and running from 18 inches to three feet in thickness, with six to 18 inches of muck overlying. The samples sent in were of first-class quality.

Samples of marl varying in quality are also in the State collection from the following points, but no data is at hand regarding the area and thickness of the deposits:

From a point two and a half miles south of Oxford, Benton County; from the land of Roeske Bros., near Michigan City, Ind.; from the land of Dr. Chenowerth, near Winchester, Ind., and from the land of Hon. J. C. Stevens, near Centerville, Ind.

CHEMICAL ANALYSES OF INDIANA MARLS.—In the table below given are included the marl analyses which are scattered through the foregoing pages. They are given here in tabular form for ready reference and comparison. The large majority of these analyses were made expressly for this report by the chemist of this Department, Dr. W. A. Noyes, of the Rose Polytechnic Institute, Terre Haute, Ind. The method of analysis as furnished by him is as follows: "The marls were dissolved in warm dilute hydrochloric acid. The solution was filtered on an asbestos (Gooch) filter, and the residue dried at 105°. The loss of this residue on ignition was counted as organic matter. The incombustible residue is recorded as the 'insoluble portion.' The 'alumina' and 'ferric oxide' given comprise only that portion of these substances which passed into solution in dilute hydrochloric acid. The ferric oxide probably represents *ferrous carbonate* in the marl. All determinations are based on the material dried at 135°."

ANALYSES OF INDIANA MARLS.

ORIGIN OF SAMPLE.			Calcium Carbonate ($CaCO_3$).	Magnesium Carbonate ($MgCO_3$).	Alumina (Al_2O_3).	Ferric Oxide (Fe_2O_3).	Calcium Sulphate ($CaSO_4$).	Insoluble Inorganic (Silica, etc.).	Organic Matter.	Total.	AUTHORITY.
LAKE.	COUNTY.	PAGE DESCRIBED.									
Hog Lake	Steuben	73	90.42	2.88	.14	.28	......	.68	4.13	98.53	W. A. Noyes.
Lime	Steuben	75	86.00	9.42	......	1.16*	......	1.08	2.32	99.98	Chas. R. Dryer.
Deep and Shallow	Steuben	77	93.29	2.67	.04	.12	......	.47	1.56	98.15	W. A. Noyes.
James	Steuben	82	92.41	2.38	......	.29	.15	1.16	1.97	98.36	W. A. Noyes.
Silver	Steuben	96	84.00	6.46	......	1.31*	......	4.52	3.68	100.00	Chas. R. Dryer.
Turkey Lakes	Lagrange	112	91.14	2.75	.61	.25	......	.85	......	95.60	W. R. Oglesbey.
Loon	Whitley and Noble	156	82.07	2.63	.41	.42	.22	5.95	6.71	98.41	W. A. Noyes.
Mud	Elkhart	164	82.89	2.04	.41	.23	......	7.94	3.67	97.18	Osborn Engineering Co.
Cooley	Elkhart	164	88.21	4.78	.52	.36	......	1.42	2.58	97.87	Osborn Engineering Co.
Syracuse	Kosciusko	182	88.49	2.71	.90	.31	1.58	1.78	4.23	100.00	S. B. Newberry.
Dewart	Kosciusko	185	92.35	3.54	.37	.16	......	2.00	2.12	100.54	A. W. Burwell.
Dewart	Kosciusko	185	84.24	2.85	.18	.30	......	4.52	5.02	97.11	W. A. Noyes.
Tippecanoe (James Basin)	Kosciusko	192	90.67	2.42	.06	.26	......	2.48	2.87	98.76	W. A. Noyes.
Tippecanoe	Kosciusko	194	91.02	2.28	......	.29	.05	2.92	2.10	98.66	W. A. Noyes.
Little Eagle	Kosciusko	205	84.75	2.84	.15	.35	.07	4.61	5.69	98.46	W. A. Noyes.
Manitou	Fulton	224	87.65	2.60	.19	.30	......	6.39	2.88	100.01	W. A. Noyes.
Maxinkuckee	Marshall	263	85.02	3.85	.12	.33	.17	5.67	3.21	98.37	W. A. Noyes.
Maxinkuckee	Marshall	263	85.38	3.50	.05	.33	.17	6.40	3.15	98.98	W. A. Noyes.
Houghton and Moore	Marshall	270	89.22	2.73	.04	.20	......	2.02	4.15	98.36	W. A. Noyes.
Notre Dame	St. Joseph	273	91.62	4.02	.05	.07	.14	.19	2.25	98.34	W. A. Noyes.
Chain and Bass	St. Joseph	275	87.92	2.64	.10	.20	.23	3.10	4.18	98.37	W. A. Noyes.
Kankakee Marsh Deposit	St. Joseph	282	91.30	2.90	......	.08	.22	.82	3.88	99.20	W. A. Noyes.
North Judson Marsh Deposit	Starke	297	89.92	2.46	.45	.74	......	1.56	4.51	99.64	W. A. Noyes.
Curran Marsh Deposit	Berrian (Mich.)	319	89.63	2.12	.37	.25	......	.42	7.55†	100.35	Frank S. Kedzie.

* This was given by Dr. Dryer as ferrous carbonate, the form in which the iron probably occurs in the marl.

† This includes undetermined matter, alkalies, etc.

OOLITE AND OOLITIC STONE FOR PORTLAND CEMENT MANUFACTURE.

By W. S. Blatchley.

As mentioned on a preceding page, the carbonate of lime used in making Portland cement can be either a marl or a limestone. There are in Indiana vast beds of limestone which possess the chemical purity and physical conditions necessary for making such cement. Practical tests in which they have been used as the carbonate of lime ingredient show the resulting cement to be superior to that in which marl was the source of the lime.

The process of manufacture where limestone is used is in general similar to that already described with the exception that the limestone has to be crushed and ground very fine before it is mixed with the clay. The Indiana limestones are soft and easily crushed and ground when first quarried, but harden on exposure. The necessary labor and expense of grinding is therefore much less when the stone is immediately used.

Oolite.—In Crawford and Harrison counties, notably near Milltown and Marengo, are extensive deposits of the purest limestone in Indiana. It is a true oolite, consisting of minute concretionary spherical masses which resemble closely the petrified eggs of fish. These are cemented together in a firm white mass, forming the stratum of stone. In Eichol's quarry at Milltown the stratum as exposed is 13 feet thick and more than 1,500 feet in length when it disappears in the bluffs of Blue River. The complete section at the quarry is as follows, No. 16 being the oolite in question:

Section at Eichol's Quarry on Northeast Side of Blue River, Opposite Milltown.

		Ft.	In.
1.	Slope mostly hidden by sandstone debris, probably all sandstone	24	..
2.	Semi-crystalline, semi-oolitic gray limestone, with fossils	4	..
3.	Light gray oolitic limestone, with pentremite bed at top	..	15
4.	Hard buff sub-crystalline limestone	3	..
5.	Hidden	4	..

		Ft.	In.
6.	Crystalline brownish-gray limestone	1	..
7.	Covered	8	..
8.	Lithographic limestone	3	..
9.	Light gray crystalline limestone	20	..
10.	Covered (limestone?)	25	..
11.	Bluish-gray lithographic limestone, buff in spots	7	..
12.	Bluish calcareous shale	..	15
13.	Sub-lithographic light drab limestone, with fine quartz sand, mustard-seed size. Some cross bedding toward top	12	..
14.	Light grayish-buff colored limestone	9	..
15.	Buff, rather soft magnesian (?) limestone	5	..
16.	Oolite, white to gray, oolitic structure imperfect locally	13	..
17.	Hard bluish gray, sub-crystalline to sub-oolitic	6	8
18.	Bluish green shale	..	2
19.	Light gray granular limestone, with a crowfoot near the middle and with occasional green blotches	5	..
20.	Shale parting	..	1
21.	Light gray sub-crystalline—sub-oolitic limestone	3	9
22.	Shale and lithographic limestone intercalated	..	24
23.	Drab colored lithographic limestone, with irregular calcite band near the middle	3	..
24.	Gray crystalline limestone	2	6
25.	Lithographic limestone with flint bands and flint concretions	7	..

Floor of quarry about 10 feet above low water in Blue River.

An analysis by Dr. Noyes of an average sample of the oolite shows its percentage composition to be as follows:

Calcium carbonate ($CaCO_3$)	98.91
Magnesium carbonate ($MgCO_3$)	0.63
Ferric oxide and alumina ($Fe_2O_3+Al_2O_3$)	0.15
Insoluble in hydrochloric acid	0.48
Total	100.17

The analysis shows the oolite to run from one to three per cent. higher in carbonate of lime than the better grades of Indiana oolitic limestone from Lawrence and Monroe counties. It is softer and therefore more easily reduced to a fine powder. At both Milltown and Marengo switches from the St. Louis Division of the Southern Railway are already in place. At Milltown Blue River can be easily dammed and cheap and permanent water-power thereby be obtained. The river at that point is about 225 feet wide, and between there and its mouth at the Ohio River, the fall is 89 feet, or about seven and a half feet to the mile.

In my report for 1899 I called attention to this deposit of oolite at Milltown, and its value as a Portland cement ingredient. A number of capitalists were afterward, by letter and in person, given full information concerning it. Finally some gentlemen from Cleveland and Detroit, who had called upon me for information relative to marl deposits, were induced to investigate it and were so pleased with both the quality and quantity of the material that they at once organized a company and secured possession of the more available portion. The same company—The Indiana Portland Cement Company—also secured the marl in and about Dewart and Milford lakes, Kosciusko County, and are now engaged in raising the capital to construct large plants at both places. The one at Milltown—utilizing the oolite—will be the sooner completed, the chances being that it will be well under way by the close of the year 1901. The company has had an analysis made showing the average composition of six limestones from the face of the Milltown quarry, one of which was the oolite. The result of this analysis was as follows:

Calcium carbonate ($CaCO_3$)	96.87
Magnesium carbonate ($MgCO_3$)	1.19
Silica (SiO_2)	.51
Alumina (Al_2O_3)	.37
Total	98.94

This analysis proves that the greater portion of the face of the cliff is well suited for the making of cement, the carbonate of lime being from three to four per cent. higher than in the better grades of marl. The only difficulty arises in the proper grinding of the hard crystalline limestones, but the company has assurance that this can be readily and cheaply done.

A section of the quarry face at Marengo is as follows:

SECTION OF QUARRY AT MARENGO, IND.

		Ft.	In.
1.	Surface clay	1 to 5	..
2.	Hard gray sub-oolitic limestone	4	6
3.	Hard light bluish-gray sub-oolitic limestone	5	..
4.	Gray sub-lithographic to sub-oolitic limestone in 6 to 36-in. strata	6	..
5.	Buff limestone, hard to rather soft	4	6
6.	Coarse crystalline gray limestone, oolitic in places	6	..
7.	Dark gray lithographic limestone	3 to 5	..
8.	Pure white to light gray oolitic limestone	2 to 4	..
9.	Buff limestone, very hard to rather soft	5	6
10.	Dark bluish-gray lithographic limestone, irregular in layers and texture	6	6

PLATE 13.

a

b

c

ILLUSTRATING QUARRYING INDUSTRY AT MILLTOWN, INDIANA.

(a) Top of lime burner at J. B. Speed & Co.'s quarry.
(b) Rock crushing plant.
(c) Quarry on east side of Blue River; output used for railway ballast.

These deposits of oolite, lying as they do in proximity to the coal fields of Dubois, Warrick and Pike counties, and also close to extensive beds of clay and shale, offer most excellent investments to capitalists in search of good sites for Portland cement manufacture.

OOLITIC LIMESTONE.—Chemical analyses and numerous practical tests show that the Indiana oolitic limestone is in every way suitable for the making of a superior grade of Portland cement. This stone is found in a strip of territory from two to fourteen miles in width which extends from Greencastle, Putnam County, to the Ohio River. It occurs in a stratum varying from a few feet to nearly one hundred feet in thickness. The principal quarries are located near Romona, Owen County; Stinesville, Ellettsville, Bloomington and Sanders, Monroe County; Oolitic, Dark Hollow and Bedford, Lawrence County; Salem, Washington County, and Corydon, Harrison County.

Few limestones are more accessible than the Indiana oolitic limestone. Occurring as it does in an almost horizontal position, it outcrops over a comparatively large area, with either no covering at all or one so light that it can easily be removed. The map of the area prepared for the Twenty-first Report of this Department shows the total length of the outcrop in Owen, Monroe and Lawrence counties to be not less than 1,600 miles. The C., I. & L. (Monon) Railway traverses the area from north to south over all the productive part, and there are also three east-west railroads and a short line known as the "Belt," which serves to connect many quarries around Bedford with the other roads. There are also short branch roads, making switch connections with one or more of these roads, running into each of the quarries.

The oolitic stone is a granular limestone, or calcareous sand rock in which both grains and cementing principle are carbonate of lime. In the common sandstones of the State the grains are hard and nearly angular. In the oolitic stone they are always soft and either round or rounded, and the cement is harder than the grains. In color the stone is either buff or blue. Its specific gravity is about 2.47, and its weight about 152 pounds per cubic foot.

Chemical analyses show the Indiana oolitic stone to be a lime carbonate of remarkable uniformity and purity. No other stone in the United States shows such a uniformity of composition over so large an area. The following analyses made in the past, mostly by the chemists of this Department, show accurately its percentage composition:

CHEMICAL ANALYSES OF INDIANA OOLITIC LIMESTONE.

Number.	LOCALITY.	Quarry.	Date.	Lime Carbonate, $CaCO_3$.	Magnesium Carbonate, $MgCO_3$.	Insoluble.	Iron Oxide, Fe_2O_3.	Alumina, Al_2O_3.	Alkalies, K_2O and Na_2O.	Water, H_2O.	Total.	Authority.
1	Bedford	Bedford, Indiana Stone Co.	1896	98.27	.84	.64	.15	......	......	......	99.90	W. A. Noyes, Rose Polytechnic Inst.
2	Hunter Valley	Hunter Bro.'s Quarry	1896	98.11	.92	.86	.16	......	......	......	100.05	W. A. Noyes, Rose Polytechnic Inst.
3	Romona	Romona Oolitic Stone Co	1896	97.90	.65	1.26	.18	......	......	......	99.99	W. A. Noyes, Rose Polytechnic Inst.
4	Twin Creek	Twin Creek Stone & Land Co.	1896	98.16	.97	.76	.15	......	......	......	100.04	W. A. Noyes, Rose Polytechnic Inst.
5	Big Creek	Indiana Steam Stone Works	......	95.80	4.01	.15	.64	......	......	1.09	100.00	L. H. Streaker, State University.
6	Big Creek	Indiana Steam Stone Works	......	95 07	4.22	.50	.71	......	......	1.19	100.00	L. H. Streaker, State University.
7	Bedford	Chicago and Bed. Stone Co.	1878	96.60	.27	.50	.98	......	.40	.61	100.00	Indiana Geological Rep., 1878, p. 95.
8	Bedford	Hoosier Quarry, buff	......	98.20	.39	.63	.39	......	......	......	99.61	Bedford Quarries Co.'s Circular.
9	Bedford	Hoosier Quarry, blue	......	97.26	.37	1.69	.49	......	......	......	99.81	Bedford Quarries Co.'s Circular.
10	Four miles E. of Spencer	Simpson & Archer	1878	96.79	.23	.70	.91	......	.32	.41	99.90	Indiana Geological Rep., 1878, p. 91.
11	Bloomington	Dunn & Dunn Quarry, white	1881	95.62	.89	1.74	.23	.06	......	.59	99.45	Indiana Geological Rep., 1881, p. 32.
12	Bloomington	Dunn & Dunn Quarry, blue.	1881	95.55	.93	1.60	.09	.09	......	.42	99.37	
13	Bloomington	Dunn & Co.	1878	95.54	.40	.65	1.00	......	.55	.25	......	Indiana Geological Rep., 1878, p. 95.
14	Stinesville	Monroe Marble Co.	1862	95.00	.22	.90	3.00	......	.83	.05	100.00	Ind. Geol. Rep, 1862, Owens, p. 137.
15	Salem	......	1886	96.04	.72	1.13	1.06	......	.15	.10	......	Indiana Geological Rep., 1886, p. 144.
16	Harrison Co	Stockslager's Quarry	1878	98.09	......	.31	.18	.14	.40	.12	......	Indiana Geological Rep., 1878, p. 96.
	Average	......		96.50	1.00	.88	.75	......	.17	.29	......	

From the table it will be seen that the percentage of carbonate of lime varies between 95 per cent. and 98.27 per cent., a variation of but little more than three per cent. in 16 different samples from widely separated localities, varying from Romona on the north to near the Ohio River on the south.

The percentage of magnesium carbonate is less than one per cent. in all the specimens except two from Big Creek, and there is a possibility in that case that the greater quantity may be due to error in analysis.

The insoluble residue which includes the silica, insoluble silicates, and organic matter, averages less than one per cent., never as high as two per cent., and only four running over one per cent. The iron and alumina combined average less than one per cent. The alkalies form a mere trifle. The last column, headed "water," in the two analyses, where it shows more than half of one per cent., includes water and loss on ignition. Probably the greater part in each is due to the unavoidable errors of analysis. Thus, from the standpoint of purity, the stone is all that could be desired, only the purest marbles and oolite giving a higher percentage of lime carbonate.

It seems strange that Indiana capital has not hitherto been invested in the manufacture of Portland cement from oolitic limestone. Dr. J. Gardner of Bedford, and others, had tests made three years and more ago which proved the fitness of the stone for such purpose. Samples of stone from the vicinity of Bedford, with copies of their analyses, were later sent by this Department to Aman Moore, then in charge of the South Bend cement factory. Under date of July 7, 1898, Mr. Moore wrote: "I have carefully examined the oolitic stone with regard to its physical properties, etc. Since the analyses show that it contains 97+ per cent. of carbonate of lime it can certainly be utilized in the manufacture of Portland cement, providing a suitable clay can be had at a reasonable price. The limestone is exceptionally good, and with a good and cheap clay, cheap fuel and good freight rates, by constructing a modern plant, equipped with the best machinery for the business, a large and paying industry could be built up in the region from whence the stone was obtained. Twenty-five thousand dollars would construct a plant that would turn out a capacity of 150 barrels per day at a cost of from 50 to 60 cents per barrel, and which, at the present price of Portland cement, would net $1.85 at the factory."

The statement that the oolitic limestone would make excellent cement was given wide circulation, both in the newspapers and in the reports of this Department, yet none of our local capitalists cared

to interest themselves in the matter. They acted in this as they have in regard to most of the other great resources of Indiana. These are being developed at the rate of nearly twenty millions of dollars yearly, yet much of the capital which is bringing about this development is owned by parties outside of the State. They reap the benefits; they pocket the profits. The people of Indiana, with hundreds of thousands of dollars of capital lying idle, are, for the most part, reluctant to invest in the resources of their State. They stand by and see our thickest coal veins, our greatest clay factories, our largest stone quarries, the majority of our oil wells, and the greater part of our natural gas property owned and operated by foreign capital.

A few millions of dollars are invested in developing these resources and pay taxes into our treasuries, but the profits, aggregating far greater sums, go into the coffers of non-resident owners. Were Indiana capital invested, both capital and profits would remain in the State, and the wealth upon which taxes are based would increase in much greater proportion.

In 1900 the Bedford Portland Cement Co. was organized by gentlemen from Minnesota and Michigan, to whom information concerning the fitness of the oolitic stone for cement purposes had been furnished by the writer. They purchased a large tract of land near Bedford upon which occurs oolitic stone, common clay and kaolin in quantity. Samples of these materials were sent to Dr. A. W. Smith, chemist at the Case School of Applied Science at Cleveland, Ohio, for analyses, which resulted as follows:

ANALYSIS OF OOLITIC LIMESTONE FROM LAND OF BEDFORD PORTLAND CEMENT CO.

Calcium carbonate ($CaCO_3$)	97.48
Magnesia (MgO)	0.61
Iron oxide (Fe_2O_3)	0.13
Alumina (Al_2O_3)	1.27
Water (H_2O)	0.15
Total	99.64

ANALYSIS OF COMMON CLAY.

Silica (SiO_2)	74.29
Alumina (Al_2O_3)	12.06
Iron oxide (Fe_2O_3)	4.92
Lime (CaO)	0.41
Magnesia (MgO)	0.68
Potash (K_2O)	0.76
Soda (Na_2O)	1.80
Total	94.92

ANALYSIS OF KAOLIN.

Silica (SiO_2)	43.55
Alumina (Al_2O_3)	36.25
Iron oxide (Fe_2O_3)	2.65
Total	82.45

Quantities of the materials were also sent to S. B. Newberry, Superintendent of the Sandusky Portland Cement Co., Sandusky, Ohio, in order that he could determine by practical experiments their fitness for cement making. In due time he made his report as follows:*

SANDUSKY PORTLAND CEMENT CO., GENERAL OFFICE AND WORKS:
SANDUSKY, OHIO, May 28, 1900.

C. A. Nimocks, Esq., Minneapolis, Minn.:

Dear Sir—As instructed by you I have made practical tests of the limestone and clay sent me at your request by Dr. J. Gardner, of Bedford, Ind., from the land of the Bedford Portland Cement Company, and respectfully submit the following report on the suitability of these materials for the manufacture of Portland cement:

The samples received consisted of a soft gray limestone, a red clay and specimens of impure kaolin.

I have examined the analyses made by Dr. A. W. Smith, of these materials, and I have not considered it necessary to repeat his analyses, but have confined my work to practical tests of the material, and tests and analysis of the resulting cement.

The limestone and clay were crushed to such fineness as to pass a No. 20 sieve, and the mixture ground with 40 per cent. of water, until the mixture, on washing through a sieve of 200 meshes to the linear inch, left scarcely any residue. The mixture was then dried and burned and a well sintered clinker resulted, which on grinding gave a cement of a light gray color, slow setting, sound in both cold and hot tests and of *extraordinary tensile strength.* The following are the results obtained in testing this cement:

Cold pat test, 7 days, sound; 28 days, sound.
Hot test, 5 hours in steam, 19 hours in boiling water, sound.
Tensile strength, neat 7 days, 713-740; 28 days, 870-935.
Tensile strength with three parts standard sand, 7 days, 415-490; 28 days, 536-585.

These tests show the cement to be of the highest quality and at least equal to any Portland cement manufactured in this country or in Europe.

*Prospectus of the Bedford Portland Cement Co., of Bedford, Ind., p. 4.

An analysis of this cement gave the following results:

Silica (SiO_2)	21.88
Alumina (Al_2O_3)	5.46
Iron oxide (Fe_2O_3)	3.02
Lime (CaO)	64.52
Magnesia (MgO)	0.84
Loss on ignition	3.12
Total	98.84

This analysis shows the cement to have a very satisfactory composition. The alumina is a little lower than in most commercial cements, but will be all the better in respect of hardening qualities and durability on this account.

Yours very truly,

S. B. NEWBERRY.

There are thousands of acres in Monroe and Lawrence counties which contain materials as good as those furnished Mr. Newberry for the experimental tests above reported upon. Millions of tons of spalls and refuse pieces of the oolitic stone, unfit for building purposes but in every way suited for cement manufacture, are thrown aside yearly from the leading quarries. The stone, when first quarried, is soft, and much more easily ground than is generally supposed. Lying, as it does, adjacent to fuel, the shales and other clays of the coal-bearing counties to the westward, there is no good reason why this oolitic stone region should not become the center of the Portland cement industry in Indiana.

THE

Silver Creek Hydraulic Limestone

OF

Southeastern Indiana.

BY C. E. SIEBENTHAL.

1900.

LETTER OF TRANSMITTAL.

Bloomington, Ind., January 10, 1901.

Dear Sir—I have the honor to transmit herewith my report upon the "Silver Creek Hydraulic Limestone," written in 1899 and embodying the results of field work done in that year, but recently gone over and brought down to date. I take pleasure in acknowledging the services of Messrs. H. M. Adkinson and F. H. H. Calhoun, graduate students at the University of Chicago, who generously gave their assistance in the gathering of the data for the paper. The thanks of the Survey are also due to Prof. Stuart Weller, of the University of Chicago, for valuable assistance in the paleontological part of this report.

Respectfully submitted,

C. E. SIEBENTHAL.

Prof. W. S. Blatchley, State Geologist.

THE SILVER CREEK HYDRAULIC LIMESTONE OF SOUTHEASTERN INDIANA.

By C. E. Siebenthal.

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I. STRATIGRAPHY.

Historical Resume.

1827.—The earliest work upon the stratigraphy of this region which has come under the notice of the writer is that of Increase A. Lapham in 1827*. Lapham describes the lowest rocks at the Falls of the Ohio as consisting of limestone, near the top of which is intercalated a bed of hydraulic limestone or "water limerock," overlain by a thin layer of coarse-grained limestone, "probably oolite or roestone," and that overlain in turn by the black shale. He

* On the Geology of the Vicinity of the Louisville and Shippingsport Canal, A. J. S., Vol. XIV, 1828, pp. 65–69.

describes the hydraulic limestone thus: "Its color is bluish gray; structure conchoidal; adheres slightly to the tongue; emits an argillaceous odor when breathed upon; and it effervesces with acids." He mentions its use in the masonry of the canal.

1841.—James Hall,* speaking of the limestone at the Falls of the Ohio, says: "The upper part of the limestone, so far as lithological characters are concerned, is a continuation of the Helderberg group, the Onondaga salt group having thinned out almost entirely, having in fact no representation except a thin layer of water lime, which is seen at the Falls of the Ohio, and the canal below Louisville, but in other localities is of less importance, and often scarcely to be recognized."

1843.—Dr. A. Clapp† in a communication, opposes Professor Hall's view that the waterlime represents the Onondaga salt group, and gives it as his belief that the waterlime is the equivalent of the Helderberg. The black slate he considers of Marcellus age.

1843.—D. D. Owen‡ correlates the black slate with the Marcellus shale and the limestone below, with the Helderburg of New York.

1843.—H. D. Rogers, in discussing Owen's paper, says that he could recognize no Hamilton in the west. He correlates the black shale with the Marcellus, and mentions finding *Orbicula corrugata* and a *Lingula* at New Albany.

1847.—Yandell & Shumard|| follow Dr. Clapp in dividing the section at the Falls of the Ohio into the coralline, the shell, and the upper limestones and the black shale, subdivided thus:

Black slate	104 feet.
Upper limestone—	
Subcrystalline limestone	8 feet.
Water limestone	12 feet.
Shell limestone—	
Subcrystalline, with shells and trilobites	16 feet.
Coralline limestone—	
Upper coralline	20 feet.
Lower coralline with Catenipora	20+ feet.

The authors agree with M. de Verneuil, whom they cite as visiting the locality in company with them, in placing the line between the Silurian and Devonian at the parting between the upper and lower coralline limestones. The limestones lying between this line and the black slate are considered from their fossils as representing

* Notes Upon the Geology of the Western States, A. J. S., Vol XLII, 1842, p. 58.
† Proc. Phil. Acad. Sci., Vol. I, 1843, pp. 177-178.
‡ On the Geology of the Western States, A. J. S., Vol. XLV, 1843, pp. 151-152, 161-162.
|| Contributions to the Geology of Kentucky, Louisville, Ky., 1847.

the Onondaga, the Corniferous and the Hamilton, and the Black slate is recognized as the equivalent of the Genessee shale.

1857.—Maj. Sidney S. Lyon,* in describing several species of crinoids from the crinoidal limestone, gives its thickness as varying from 4 to 8 feet. Underlying this is the hydraulic limestone, varying from 18 feet at the falls to 4 or 6 inches on Bear Grass Creek. He notes a conglomerate bed of ferruginous gravel in the lower part of the crinoidal limestone and another at the base of the hydraulic limestone.

1859.—Lyon and Cassedav,† in describing *Megistocrinus rugosus* give it as occurring in rocks a few feet below the black slate on Bear Grass Creek, "in Devonian rocks of the age of the Hamilton Group." As near as may be judged from the description, the location must have been in the crinoidal limestone. This is the first reference of these rocks to the Hamilton.

1860.—Maj. Sidney S. Lyon‡ divides the beds at the Falls according to their characteristic fossils as follows:

Black slate	50 to 100 feet.
Encrinital limestone	8 feet.
Hydraulic limestone	20 feet.
Spirifer cultragulatus bed	3 feet.
Nucleocrinus bed	2 feet.
Spirifer gregaria and Turbo beds	10 feet.
Coral beds	10 feet.
Catenipora escharoides beds	40 feet.

The geological age of these beds is not discussed except that the author suggests that the Subcarboniferous age of the black slate is indicated by the goniatites of Rockford, Indiana. It has since been shown that the goniatites were derived from a stratum overlying the black shale. The author points out that the hydraulic limestone, to which he assigns a thickness of twenty feet at the Falls, has thinned out to four inches at a point three miles to the southeast, and states that all of the beds from the Encrinital limestone to the Catenipora limestone thin out and disappear within a distance of 20 miles south of Louisville.

1874.—Prof. W. W. Borden|| gives the following succession of the rocks in Clark and Floyd counties:

* Kentucky Geological Survey, Vol. III, p. 484.
† A. J S., Second Series, Vol. XXVIII, 1859, p. 244.
‡ Trans. St. Louis Acad. Sci., Vol. I, 186', pp. 612–621.
|| Geological Survey of Indiana, 1873, pp. 134–189.

New Albany black slate	104 feet.
Crinoidal limestone	3½ to 4 feet.
Hydraulic limestone	14 to 16 feet.
Corniferous limestone	22 feet.

The limestone below the Hydraulic limestone is placed in the Corniferous and the Hydraulic and Crinoidal limestones are placed in the Hamilton, to which the New Albany Black slate is provisionally added. (See section, loc. cit., p. 172.)

1875.—Professor Borden in the report on Scott County* notes the occurrence in the New Albany Black shale, of *Leiorhynchus quadricostatum* Hall, *Chonetes lepidus* Hall, and *Tentaculites (Styliola) fissurella* Con., and for this reason refers it to the Genessee which he makes a subdivision of the Hamilton period. From the Crinoidal limestone he cites *Tropidoleptus carinatus* Con., and *Chonetes coronatus* Con., which causes him to place that limestone, together with the Hydraulic limestone, in the Hamilton proper.

1879.—James Hall† reviews the work of previous writers, and gives a tabulated list of the fossils occurring in the Devonian limestones at the Falls of the Ohio, and their representation in the Hamilton and Chemung groups of New York. The list clearly substantiates Mr. Hall's view that the Encrinital and Hydraulic limestones are of Hamilton age. Out of a total of 90 species occurring in the Encrinital and Hydraulic limestones, 55 are represented in the Hamilton of New York, 15 are represented in the Corniferous of New York, and 14 are common to both Corniferous and Hamilton.

The upper limit of the Corniferous is characterized by the abundant presence of *Spirifer acuminatus*.

The New Albany Black shale, on paleontologic and stratigraphic grounds, is referred to the Genessee.

1897.—Dr. August Foerste‡ describes the occurrence of New Albany Black shale, the Crinoidal limestone, the Hydraulic limestone and the Corniferous, at various points in the vicinity of Charlestown, Indiana, but makes no effort at their correlation. At the cement quarry, one and one-half miles west of Charlestown, he notes that the lower part of the Crinoidal limestone contains many small rounded black pebbles.

1899.—E. M. Kindle|| gives numerous sections and lists of fossils from many localities in the Devonian and Subcarboniferous of

* Geological Survey of Indiana, 1874, pp. 112-134.
† Palaeontology of New York, Vol. V, Part II, pp. 139-154.
‡ Indiana, Dept. Geol. and Natural Res., 22d Ann. Rep., pp. 213-288.
|| Bulletins of American Palaeontology, No. 12. The Devonian and Lower Carboniferous Faunas of Southern Indiana and Central Kentucky.

southern Indiana, some of them within the area which we have under consideration. A brief résumé of the contentions which have arisen over the ages of the various formations is followed by the correlations which the author thinks best justified.

The Knobstone is divided into two formations. The upper one, consisting of sandstones and arenaceous shales, is found by its fauna to be the equivalent of a similar formation further north in Indiana, described by Hopkins* under the name of Riverside sandstone, and consequently that name is adpoted. The lower member, consisting of blue shales, had previously been named the New Providence shale. Lists of fossils are given from both members which show their affinities to be of the closest kind. The Knobstone as a whole is found to be the faunal equivalent of the Waverly sandstone of the Ohio section, and the Osage group of the Mississippian section. Selecting the most abundant and characteristic fossil in each, the upper member or Riverside sandstone is denominated the *Reticularia pseudolineata* zone, and the lower or New Providence shale, the *Rhipidomella oweni* zone of the Eocarboniferous.

The Rockford limestone holds a surprisingly rich fauna, the cephalopoda comprising one-third of the whole. Attention is called to its adventitious character. From the fact that in Kentucky a bed of shelly limestone, carrying a characteristic New Providence shale fauna, occupies a position between the Black shale and the New Providence shale, in other words, occupies the horizon of the Rockford limestone, the author argues the contemporaneity of the Rockford limestone and the lower part of the New Providence shale. On lithologic, stratigraphic and paleontologic grounds, the author rejects Meek's correlation with the Choteau limestone of Missouri, and makes it the equivalent of the Lithographic or Louisiana limestone of the later Missouri reports.

The formation is characterized as the *Munsteroceras oweni* zone the Eocarboniferous.

The New Albany Black shale, on account of its meagre and undiagnostic fauna, has offered the most difficult problem in correlation of all the Devonian. The weight of evidence, however, seems to most closely ally it with the Genessee shale of the New York section. It is made the *Styliola fissurella* zone of the Mesodevonian.

The Sellersburg beds, as proposed by the author, include the upper part of the Devonian limestone from the New Albany Black

*Indiana Department of Geology and Natural Resources, 20th Annual Report, 1895, p. 287.

shale down to the bottom of the lowest beds worked at the cement quarries in the vicinity of Sellersburg. The formations comprised within these limits are the cement beds and a thin, overlying bed of limestone. Faunally, these two members are very closely related, and they are both referred to the Hamilton. They form the *Spirifer granuliferus* zone of the Mesodevonian.

The Jeffersonville limestone is a term introduced by the writer to comprise the lower part of the Devonian, lying between the Sellersburg beds and the Silurian. The fauna has very close affinities with the Corniferous. It is denominated the *Spirifer acuminatus* zone of the Devonian.

Stratigraphy and Paleontology.

Though this investigation had to do with the members of the Devonian only, for the sake of completeness the members of the underlying and overlying formations, within the area comprised by the accompanying map, have been delineated upon it, and short descriptions are incorporated herein. The geological section with the New York and Mississippian equivalents as ordinarily given is as follows:

Subcarboniferous—	
Knobstone	Kinderhook.
Rockford limestone	Choteau.
Devonian—	
New Albany Black shale	Genessee.
Sellersburg limestone	Hamilton.
Silver Creek Hydraulic limestone	Hamilton.
Jeffersonville limestone	Corniferous.
Pendleton sandstone	Schoharie.
Silurian—	
Upper Silurian	Niagara-Clinton.
Lower Silurian	Hudson River.

Of these formations several are omitted from the map for the reason that their outcrops are too limited in extent to be delineated upon a map of that scale. Such formations may be located closely enough by the line of parting between the overlying and underlying formations. Notably, the Rockford limestone may be located by the line separating the Knobstone and the New Albany shale. The Sellersburg limestone has uniformly been included with the Silver Creek limestone where that formation has been delineated. The eastern border of the Silver Creek limestone has usually been found in a flat plain, without outcrops, and covered with drift. In such places by

means of well sections it was possible to do no more than distinguish between the limestone and the shale, and the parting as mapped is such, thus throwing the Sellersburg and Clear Creek limestones in with the Jeffersonville limestone. The Pendleton sandstone has not been found within the limits of this region, but what is probably that formation has been found not far north, and may be found here. Its proper horizon would be the parting between the Niagara and the Jeffersonville limestones.

The Knobstone was originally included by D. D. Owen with the next overlying formation under the name Calcareo-siliceous or Encrinital limestone series. It was first considered separately by Owen and Norwood* who considered "the formation of the knobs" to be the basal formation of the Carboniferous. The use of the word Knobstone to designate this formation first occurred in 1859 in the revised reprint of D. D. Owen's Geological Reconnoissance of Indiana. The formation consists of a series of alternating, friable, arenaceous shales and sandstones, ranging from 350 to 600 feet in thickness. The outcrop reaches its maximum development in Morgan, Brown and Jackson counties, where it varies from 30 to 40 miles in width. To the south it narrows rapidly, and west of the region covered by this report is in some places not over two miles in width. It is in the main unfossiliferous, but at intervals there are intercalated calcareous septaria and lenticular beds of limestone which hold rich faunas. In rare places the Knobstone itself is fossiliferous. Recently considerable work has been done upon the paleontology of this formation, the results of which are given in the paper by E. M. Kindle, which has been summarized above.

The Rockford Goniatite limestone was first noted by Owen and Norwood in the paper cited above, and referred by them to the Devonian. It is a thin but very persistent bed of ferruginous limestone and calcareous shale of limited areal extent, coming between the Knobstone and the New Albany shale and furnishing the famous fossils which led, after much controversy, to its recognition as the base of the Carboniferous.

The New Albany Black shale was named by Prof. W. W. Borden in 1873, from the city of that name, where its thickness was investigated by borings by Dr. Clapp, and found to be 104 feet. In other places it is reported as much as 140 feet, but in the region of the cement rock (where its whole thickness is not exposed) it varies from nothing to about 60 feet.

* Researches Among the Protozoic and Carboniferous Rocks of Central Kentucky, made during the summer of 1846, by D. D. Owen, M.D., and J. G. Norwood, M.D., St. Louis, 1847.

It is a black, fissile, in places sheety, shale, which sometimes carries enough bituminous matter to make it burn freely. It of course does not burn to ashes, but when the oil is all burned off the shale is left with a reddish, or drab, baked appearance. For a more detailed account of the black shale the reader is referred to the excellent article by Mr. Hans Duden in the Twenty-first Annual Report of this Department.

The earlier correlation of this shale was with the Marcellus of New York, but in time it came to be referred to the Genessee of New York. An able discussion of the whole matter is given by Mr. Geo. H. Girty of the U. S. Geological Survey in an article in the American Journal of Science for 1898, Vol. IV, pp. 384-395.

In the vicinity of Lexington, Professor Borden found the following fossils in the Black shale, viz.: *Leiorhynchus quadricostatum* Hall; *Chonetes lepidus* Hall; *Tentaculites (Styliola) fissurella* Hall; and *Cardiola radians,* all Genessee forms.

The Sellersburg limestone is that bed of white to gray crystalline limestone which overlies the cement rock, which underlies the New Albany Black shale, and which by various writers has been alluded to as the Crinoidal limestone, and to distinguish it from a crinoidal layer in the Corniferous, as the Upper Crinoidal limestone. It is an important formation, and while not very thick it is very persistent, stretching from the Falls as far north as the writer has investigated, that is, to the lower edge of Decatur County. In that region a stone occupying a similar stratigraphic position has been quarried and marketed under the title of the brown stone, or the North Vernon Blue stone. It seems undesirable to perpetuate this name, however, as more than one formation has been sold under that title, and moreover, the stone as sold is not the typical facies of the formation.

Recently E. M. Kindle, in the paper referred to above, has proposed the name Sellersburg beds to include both the Crinoidal and the Hydraulic limestones. The disparity in chemical composition and lithologic appearance of these two formations warrants the use, we think, of separate names, and for convenience of treatment we have adopted different names in this report. We have retained the term Sellersburg limestone, but have limited its application as noted in the beginning of this paragraph.

Any outcrop or quarry in the vicinity which exposes both the Black shale and the cement rock will also expose from five to eight and rarely 10 feet of the Sellersburg limestone. In rare instances, however, the Sellersburg limestone is absent from the section, notably in those given for the *Ohio Valley Cement Co.* quarry and the quarry

of the *Standard Cement Co.* In such cases there is an excessive thickness of the Silver Creek limestone, which comes about by the addition on top of several feet of the calcareous cherty bastard rock. It indicates that in localities the deposition conditions of the cement rock prevailed on through the time of deposition of the Sellersburg limestone.

It will be noticed in the detailed sections in the pages following that at or near the base of the Sellersburg limestone there is generally a conglomeritic band marked by small shining black pebbles, of which the interior is a dull drab color. In very rare instances fragments of fossils are found in these pebbles, notably the characteristic *Chonetes yandellus.* Frequently the basal portion of the limestone is sandy and occasionally there is a definite arenaceous stratum intercalated between the cement rock and the Sellersburg limestone, and in this the pebbles will be especially abundant. These pebbles are clearly rounded and waterworn, and, coming as they do, in the sandy matrix, the natural conclusion is that they represent a basal conglomerate formed by the beating of the waves upon the "bastard" layers of the cement rock, wearing away the more calcareous portions and rounding down the siliceous concretions to the shape of the pebbles, at the same time staining them a dark color. However, the chemical composition of the pebbles presents a serious objection to this view. Qualitative tests show that they are highly phosphatic. But the concretionary masses in the "bastard" layers of the cement rock are siliceous, sometimes pure flint, and are not phosphatic to more than a barely appreciable extent. For the present the origin of the pebbles must remain in abeyance.

In this connection it is interesting to note that the black nodular phosphates of Tennessee described by Hayes* have pebbles very much as these, and occupy very much the same stratigraphic position. Also that the phospate beds of North Arkansas, described by Dr. J. C. Branner,† have just such pebbles which are the source of the phosphate.

These phosphatic pebbles are of economic interest, but not of economic importance, since it is not probable that they will be found within the State in sufficient abundance to justify exploitation for fertilizing purposes.

At the top of the limestone and coming between that and the black shale there is almost invariably a bed of iron ore about two inches in thickness. In many places this is conglomeritic, notably

*Sixteenth Ann. Rep. U. S. G. S., 1894-5, Part IV, pp. 610-630, Seventeenth Ann. Rep. U. S. G. S., 1895-6, Part II, pp. 519-550.

†Transactions A. I. M. E., Vol. XXVI, 1896, pp. 580-598.

in the side of the cut which faces the depot at Lexington, Scott County. Here the small pebbles are imbedded in two inches of solid bright iron pyrites. In other places the iron bed is replaced by a gritty calcareous stratum, similar in all respects to that beneath the Sellersburg limestone, and bearing pebbles indistinguishable from the pebbles in that formation, except that usually this conglomerate is more stained with iron than that at the base of the limestone. In one place, at Hess's Ford on the Muscatatuck River, among the pebbles in the upper conglomerate was one of a crystalline texture, which is plainly a stranger to Indiana. It might have found its way there in the maw of some fish, however.

In another place the shale is separated from the Sellersburg limestone by a stratum of iron ore one inch in thickness. The top of the limestone is wrinkled or wavy and in the hollows there is collected conglomerate.

As has been shown in the review of the literature on the preceding pages, the earlier custom was to refer the whole limestone series to the Upper Helderberg or Corniferous of New York. Lyon and Casseday were the first to refer rocks (which we doubtfully identify with the Sellersburg limestone) to the Hamilton. But in 1874 Prof. W. W. Borden,* as above noted, gave a table of correlation of which the following is part:

New Albany Black shale	?
Crinoidal limestone	Hamilton Group.
Hydraulic limestone	
Corniferous limestone	Corniferous.

In the text he makes it clear that he is in doubt about the age of the black shale because of the lack of fossils. But one year later† he cites *Leiorhynchus quadricostatum* Hall, *Chonetes lepidus* Hall, *Tentaculites (Styliola) fissurella* Hall and *Cardiola radians*, all Genessee species, from the New Albany Black shale and refers it to the Genessee period of the Hamilton group. From the Crinoidal limestone he cites *Tropidoleptus carinatus* Con. and *Chonetes coronatus* Con., two of the three Hamilton forms *par excellence* and naturally reiterates his reference of this formation to the Hamilton.

Prof. Jas. Hall, in 1879, came to the conclusion that the Crinoidal and Hydraulic limestones were not Upper Helderburg as he had before supposed, and set about showing that everybody else, as well as himself, had been mistaken. He quotes Professor Borden's table of correlation above from the report of 1873 as follows:‡

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* Geol. Surv. of Ind., 1875, p. 172.
† Geol. Surv. of Ind., 1874, pp. 122, et seq.
‡ Paleontology of New York, Vol. V, Part II, pp. 139-154.

New Albany Black shale............	**? Hamilton Group.**
Crinoidal limestone	
Hydraulic limestone.	
Corniferous limestone	**Upper Helderburg Group.**

Attention is called to the position of the interrogation point. In a foot note* Mr. Hall says: "Since this reference does not appear in the succeeding reports, the view then entertained may have been subsequently modified." This in spite of the fact that on the preceding page he quotes Professor Borden in the report for 1874 as citing *Tropidoleptus carinatus* and *Chonetes coronatus* Con. (Hamilton Group of New York), as occurring in the crinoidal limestone. Apparently Professor Hall thought that the author had provisionally referred the formation to the Hamilton, but on finding it contained *Tropidoleptus carinatus* and *Chonetes coronatus* he had lost all confidence in his correlation and was afraid to suggest another. It might be noted that Professor Hall attributes the whole correlation to Prof. Cox, whereas both of the county reports referred to bear Professor Borden's name at the head. It is clear then that to Prof. W. W. Borden is due the honor of first clearly recognizing the Hamilton age of the Crinoidal (Sellersburg) limestone and the Hydraulic (Silver Creek) limestone.

Many lists of fossils from the Hamilton in the vicinity of the Falls of the Ohio have been given, but usually no distinction has been made as to whether they came from the crinoidal limestone or the hydraulic limestone. The following lists of fossils from the Sellersburg limestone are appended with the full knowledge that they are far from complete and might be much extended by closer and further search.

From the Belknap quarry, one mile south of Sellersburg, were obtained the following forms:

Stropheodonta perplana Con.
Stropheodonta concava Hall.
Stropheodonta demissa Con.
Spirifer hobbsi Nett.
Spirifer granulosus Con
Spirifer audaculus Con.
Rhipidomella vanuxemi Hall.
Camarotoechia sappho Hall.
Centronella impressa Hall.
Pentagonia unisulcata Con.
Productella spinulicosta Hall.
Pholidostrophia iowaensis Owen,
Atrypa reticularis Linn.
Capulus dumosum Con.
Orthonychia conicum Hall.
Platyostoma lineatum Con.
Phacops rana Green.
Proëtus macrocephalus Hall.
Proëtus sp? (large pygidium only).
Diphyphyllum sp?
Zophrentis sp?
Crinoid stems.
Bryozoa, several genera.

* Loc. cit., p. 154.

From the Sellersburg limestone overlying the cement rock in the quarry of the Indiana Cement Co., two miles south of Charlestown, the following species were collected:

Megistocrinus rugosus L. and C.	*Athyris fultonensis* Swal.
Ancyrocrinus bulbosus Hall.	*Orthonychia conicum* Hall.
Gennaeocrinus kentuckiensis Shum.	*Pleurotomaria?* sp.

The Silver Creek Hydraulic Limestone lies beneath the Sellersburg limestone, and between it and the Jeffersonville limestone and is thus the lower part of the Sellersburg beds of Kindle. It ranges in thickness from 15 or 16 feet in the Silver Creek region, to eight or 10 feet in the Charlestown region, and five or six feet in the vicinity of Lexington, thinning out rapidly to the north and disappearing altogether as a persistent formation in the northern part of Scott County. It receives its name from the fact that it is typically developed in the vicinity of Silver Creek, in Clark County, Indiana. Furthermore, the first cement sold under a special name was called the Silver Creek cement; hence the name is quite fitting. It is a homogenous, fine-grained, bluish to drab argillaceous magnesian limestone, the calcined form of which has the property of *hydraulicity*.

As the texture and composition of this rock are taken up in detail in another place, we will not concern ourselves further with their consideration at this point.

The first attempt at correlating this formation with those of the East was made by James Hall in 1841, when he correlated the Hydraulic limestone with the water-lime (Onondaga) and the Sellersburg limestone with the Helderburg. This was soon shown to be an error, and in time the Hamilton age of the formation was recognized. Though even yet the descriptive articles in the statistical publications generally put down the Silver Creek limestone and the Milwaukee Hydraulic limestone as of Upper Silurian age. As shown by the fossils the age of this formation is the same as that of the Sellersburg limestone, and what has been said in regard to the controversy over the age of the latter applies as well to the Silver Creek limestone. The most characteristic fossil is the little *Chonetes yandellanus* Hall, which is found in great numbers everywhere in this limestone. *Atrypa reticularis* and *Spirifer granulosus* are also abundant both in this limestone and in the Sellersburg limestone.

Hall gives a list of 90 species occurring in the Crinoidal (Sellersburg) and Hydraulic (Silver Creek) limestones; but in the list the two faunas were not separated. In connection with this investigation

collections have been made from the cement rock at different points in the neighborhood of Sellersburg, and a list of the species found is here appended:

Chonetes yandellanus Hall.
Tropidoleptus carinatus Con.
Atrypa reticularis Linn.
Spirifer fornacula Hall
Spirifer granulosus Con.
Spirifer varicosus Hall.
Stropheodonta concava Hall.
Stropheodonta perplana Con.
Camarotoechia sappho? Hall.
Aviculopecten princeps Con.
Phacops bufo? (pygidium only).

The Jeffersonville limestone is that mass of white to bluish gray, crystalline, fossiliferous, flaggy limestone lying below the Silver Creek limestone and above the Niagara. It has a thickness of 22 to 30 feet in the region of Clark County, but gets much thicker to the north, ranging up to 50 and 60 feet in the neighborhood of North Vernon.

This limestone has long been recognized as Corniferous in age, and until recently has always been referred to as the Corniferous. In the paper by Mr. Kindle, however, which has been cited above, the formation is called the Jeffersonville limestone from the fact that it is typically exposed at the Falls of the Ohio, near that city, which has long been a favorite collecting ground for Corniferous fossils. As has been noted on a preceding page, Major Lyon subdivided the rocks of this formation into several beds characterized by the predominance of certain fossils. It has not been feasible or possible in this investigation to carry out these subdivisions, but they do not militate against the employment of the larger geographical name.

The upper member of the Jeffersonville limestone is marked by the abundant occurrence of *Spirifer acuminatus, Stropheodonta demissa* and *Stropheodonta hemispherica.*

The following species were collected from the Jeffersonville limestone immediately beneath the Silver Creek limestone where it outcrops in the road in the western corner of Section 113, two miles northeast of Sellersburg:*

Spirifer acuminatus Con.
Spirifer fornacula Hall.
Stropheodonta concava Hall.
Stropheodonta demissa Con.
Stropheodonta perplana Con.
Schizophoria propinqua Hall.
Glyptodesma erectum Con.
Capulus dumosum Con.
Euomphalus decewi Bill.
Bellerophon sp?
Favosites hemisphericus Troost.
Zaphrentis gigantea Lesueur.

* A section of the rocks at this point is given on page 352.

Rhipidomella vanuxemi Hall.
Atrypa reticularis Linn.
Athyris fultonensis Swallow.
Paracyclas elliptica Hall.
Phacops cristata Hall.
Proëtus crassimarginatus? Hall.
Bryozoa, several genera.
Fish teeth.

In the west bank of Silver Creek by the side of the Sellersburg and Watson road, at a distance of 10 to 15 feet below the top of the Jeffersonville limestone, the following forms are found:

Spirifer gregarius Clapp.
Spirifer fornacula Hall.
Spirifer acuminatus Con.
Chonetes mucronatus? Hall.
Atrypa reticularis Linn.
Stropheodonta perplana Con.
Stropheodonta concava Hall.
Stropheodonta demissa Con.
Athyris fultonensis Swallow.
Camarotoechia sappho? Hall.
Leptaena rhomboidalis Wilckens.
Rhipidomella vanuxemi Hall.
Glyptodesma erectum Con.
Aviculopecten princeps Con.
Paracyclas elliptica Hall.
Bellerophon pelops? Hall.
Euomphalus decewi Billings.
Turbo shumardi Verneuil.
Loxonema sp?
Dalmanites (*Coronura*) *aspectans* Con.
Zaphrentis gigantea Lesueur.
Bryozoa, several genera.
Crinoid stems and plates.

Pendleton Sandstone.—This formation was named by Prof. E. T. Cox in 1869,* from the village of Pendleton, Madison County, Indiana, where it is best exposed. He more fully described it in 1878.† It consists of 15 feet of heavy-bedded soft white sandstone, the upper part of which is fossiliferous. Above are the fossiliferous limestones of the Corniferous and below, those of the Niagara. The fossils listed from this sandstone at the original locality are as follows:

Spirifer fimbriata.
Spirifer umbonata
Conocardium trigonale
Zaphrentis gigantea.
Pleurotomaria sp?
Diphyphyllum caespitorum?
Cladopora fibrosa?
Tentaculites scalariformis.

Professor Hall‡ has pronounced the fossils to be of the age of the Schoharie Grit of New York, the basal portion of the Corniferous. These rocks are described from Huntington and Madison counties.

Well sections in the neighborhood of Alert, Decatur County, show several feet of sandstone at about the right stratigraphic position to be the equivalent of the Pendleton sandstone.

* Geological Survey of Indiana, 1869, p. 7.
† Geological Survey of Indiana, 1878, pp. 60–62.
‡ Loc. cit., p. 60, foot-note.

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....	20	0

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Near a spring in the western part of section 39, the cement, characterized by *Chonetes yandellanus*, shows to a depth of five feet and is underlain by the *Stropheodonta demissa* bed and overlain by six to eight feet of mixed chert and drab limestone.

At forks of road in south corner of section 53 there are indications of shale overlying three to four feet of chert and gray limestone which is underlain by two feet of somewhat fetid, fine-grained drab limestone, blue on unweathered surface, containing *Chonetes yandellanus*. The bottom of the ledge is concealed.

Between this point and Charlestown the outcrop traverses the top of a flat ridge and is concealed by soil and drift so that it can be determined only in a general sort of way.

Silver Creek Region.—The cement rock disappears beneath the New Albany Black shale in the bed of Silver Creek about a mile below the Black Diamond mill. It has its outcrop in the slopes of the west bank of the creek and in the tributaries which come in from the west as far up as the lower side of section 85, where it finally disappears beneath the Black shale. In the descriptions of the properties of the firms engaged in the manufacture of this cement will be found sections of the Black Diamond, Banner, Hoosier, Globe, Belknap, New Albany, Golden Rule, Speed's and Haussdale quarries. An examination of these in their proper order will give a clear idea of the character of the cement ledge on the west bank of Silver Creek. To these may be added a section observed near the west bank of the creek near the center of section 168:

Soil and drift	8 to 10 feet.
Crystalline limestone	3 feet.
Cement	10 feet.

The bottom of the cement must be about level with the bed of the creek.

The details of the distribution may be gained from the general map appended to the report.

The cement rock shows to a depth of six or eight feet just north of Stony Point church, on the north bank of Stinking Fork Creek, in the west corner of section 152. It is underlain by the *Stropheodonta demissa* bed and overlain by drift. Cement rock shows 500 yards west on the road to Silver Creek church and in the road one-half mile northwest of Stony Point church.

Cement rock with a covering of Sellersburg limestone shows in the road near the creek in the east corner of section 170. The full thickness can not be seen as the bottom is concealed.

In the east corner of section 190, the Sellersburg limestone shows a thickness of five feet below the shale. The lower part of the ledge is sandy. The cement rock crops out below several feet in thickness, but the bottom of the ledge can not be seen.

Along the road between sections 153 and 154, and sections 171 and 172 the cement rock shows beneath the shale to a depth of five or six feet without the full thickness being exposed.

In the side of the slope to the small drain which crosses the road near the center of section 154 this section is seen:

New Albany black shale	12 to 15 feet.
Bastard limestone	8 feet.
Cement rock	12 feet.

A small brook which crosses the road in the western part of section 136 exposes cement eight to ten feet overlain by 50+ feet of Black shale. A mile west along the same road in the south corner of section 153 the cement rock has a thickness of 10 feet as exposed. At the angle in the road in the north central part of section 134 the following section is seen:

New Albany black shale	15 feet.
Gray crystalline limestone	3 feet.
Bastard limestone with chert	3 feet.
Cement rock	5 feet.

The bottom of the cement ledge is not exposed, but down the branch at the same level shaly limestone shows, with *Stropheodonta demissa* and *Chonetes yandellanus* very plentiful. The *Chonetes* is also present in the cement rock.

One-half mile west of the above section in the west corner of section 134 the cement shows a thickness of 10 or 11 feet, underlain by the *Stropheodonta demissa* bed. The cement is apparently of good quality and there would be little stripping in the neighborhood.

The road leading west from the last station between sections 133 and 151 shows thickness of cement of six and eight feet without the bottom being exposed. As shown on the map large areas here would have only dirt stripping and would be found of good quality.

A well on the land of A. P. Hauss in the south corner of section 151 was as follows:

Soil and clay	8 feet.
Cement rock	16 feet.
Crystalline limestone	3 feet.

A section of Speed's new quarry is given in the description of that property. (See p. 385.) The knoll just south of the quarry shows a thickness of 20 feet of Black shale.

Further south along the same road near its intersection with the road on the line between sections 113-132 we get this section:

New Albany black shale	2 feet.
Gray crystalline limestone with pebbles at base	3 feet.
Gritty buff cement rock	6 feet.
Fine-grained buff cement rock	8 feet.
Crystalline limestone	20 feet.

A list of fossils found in the crystalline (Jeffersonville) limestone immediately beneath the cement rock is given on page 346.

In section 68 the creek bluff shows a section of the Charlestown limestone 28 to 30 feet in thickness.

At the east corner of section 49 we get the section:

	Ft.	In.
Siliceous limestone	1	6
Crystalline limestone	2	6
Cement rock	4 to 6	

The bottom of the cement rock is not shown.

Sections at the quarries of the Ohio Valley Cement Co., Silver Creek Cement Co., Kentucky and Indiana Cement Co., and the Queen City Cement Co., will be given in the descriptions of those properties.

A section at the county quarry near the center of section 24 gives the following:

Soil	1 foot.
New Albany black shale	3 feet.
Fine grained crystalline limestone	5 feet.
Bastard black limestone with chert	5 feet.
Cement below.	

Three hundred yards north of the crossing of the B. & O. Railway and the road on the line between sections 51 and 52 there is an outcrop of cement rock as follows:

New Albany black shale	6 feet.
Heavy blue crystalline limestone	10 feet.
Cement rock with *Chonetes yandellanus*	5 feet.

The section is underlain by the *Stropheodonta demissa* bed.

At the northeast corner of section 51 the cement has thickened to 8 feet, and a half mile further on to 10 feet. Six hundred yards southwest of the east corner of section 134 we have this section:

New Albany black shale	2 feet.
Gray crystalline limestone	2 feet.
Chert	3 feet.
Cement rock, fair quality	10 feet.

Near the middle of the southeast side of section 114 a well section is as follows:

Soil	10 feet.
New Albany black shale	1 foot.
Bastard rock	4 feet.
Cement rock	7 feet.

At the angle in the road near the center of section 94 there is the following exposure:

Soil	3 feet.
Bastard rock	7 feet.
Cement rock	7 feet.

In the south corner of section 116 the exposure is as follows:

Soil	3 feet.
New Albany black shale	2 feet.
Bastard rock	5 feet.
Cement rock	8 feet.

Continuing on toward Charlestown the Black shale shows a thickness of 35 or 40 feet.

On the north bank of Pleasant Run on the line between sections 116 and 117 this section is shown:

Black shale	2 feet.
Residual chert on surface	6 feet.
Cement rock	10 feet.
Heavy gray crystalline limestone	2 feet.
Shaly gray crystalline limestone	2 feet.
Heavy gray crystalline limestone	2 feet.
Heavy limestone to bed of creek	25 feet.
Coralline limestone in creek	0 feet.

Along the road which runs up Pleasant Run a half mile northwest of Charlestown there is an exposure of cement rock seven feet in thickness, overlain by cherty rock, of which one foot is visible. The cement rock contains many *Spirifer granulosus* and *Chonetes yandellanus*.

A well at A. C. Smith's on the highest part of West Charlestown yielded this section:

Soil and clay	6 feet.
Rotten black shale	2 feet.
Bastard rock with chert	4 feet.
Gray crystalline limestone	1 foot.
Cement rock below	?

South and East of Charlestown.—At the north corner of section 74, as well as further south in the same section and other high points in the neighborhood, the limestone contains *Stropheodonta demissa* and probably comes just beneath the cement rock of which no sign appears.

At the east edge of the town of Charlestown on the New Washington road a well at the house of Mr. Jas. A. Johnson gave this section:

Soil and clay	10 feet.
Cement rock	14 feet.
Hard limestone	8 feet.

Just east of Mr. Johnson's the drain exposes 10 feet of massive shaly limestone containing *Stropheodonta demissa.*

Where the road crosses the stream in section 119 the Jeffersonville limestone is exposed to a thickness of 20 feet.

North of where the road crosses Nine Penny Branch in section 138 this section is exposed:

Soil	10 to 12 feet.
Bastard rock	5 feet.
Sandy limestone	5 feet.
Cement rock	8 feet.

A section of the Standard Cement Co.'s quarry is given under the description of that property. Near the center of section 157 is this section:

Shale	15 feet.
Sandy crystalline limestone	12 feet.
Cement rock	6 feet.
Heavy bedded crystalline limestone	12 feet.
Fine grained drab limestone	20 feet.

In the western corner of section 157 the following is exposed:

New Albany black shale	2+ feet.
Bastard rock with much flint	4 feet.
Cement rock with *Chonetes yandellanus*	6 feet.
Jeffersonville limestone	2+ feet.

Where the road goes up the hill in the south corner of section 176 we get this section:

Drift	8 to 10 feet.
Shale	? feet.
Cement rock, shaly	9 feet.
Jeffersonville limestone	25 feet.

At the forks of the road near the center of section 177 this is the section:

	Ft.	In.
Till	4 to 5	..
New Albany black shale	10	..
Gray crystalline limestone	1	8
Shaly buff cement	8	..
Shaly crystalline limestone	12	..

The bed below the cement shows *Spirifer acuminatus* and *Stropheodonta demissa.*

One-half mile southeast of New Market, where the road goes up the hill, this section is exposed:

	Ft.	In.
Drift	8 to 10	0
New Albany black shale	0	6
Hard gray crystalline limestone	4	0
Buff cement rock with *Chonetes yandellanus*	12	0

The limestone beneath the cement shows *Stropheodonta demissa.*

At two places along the road between Runyon postoffice and Fourteen Mile Creek, at the forks of the road one-half mile east of Runyon postoffice, is a fine grained drab limestone containing *Chonetes yandellanus* in abundance and *Spirifer gregarius.* It is overlain by about a foot of fossiliferous shaly limestone and underlain by cherty limestone.

A limestone similar in all respects outcrops in the road at the east corner of section 123. It is overlain by 12 to 14 inches of impure limestone with *Chonetes yandellanus* and *Spirifer gregarius* and underlain by a tough dark fetid limestone.

At the big spring near the center of section 163 there is this section:

Shaly crystalline limestone	2 feet.
Drab fine-grained fetid cement rock	5 feet.
Heavy bedded crystalline limestone	4 feet.

The overlying limestone contains a great many *Spirifer gregarius* and some *Chonetes yandellanus, Euomphalus, Stropheodonta,* etc. The lower two feet contains a great many corals.

Near where the New Washington-Charlestown road crosses the northeast line of Clark's Grant there is an outcrop of eight feet of drab fetid limestone with a few corals, which appears to belong to the massive magnesian limestone which overlies the Waldron shale in this region.

In the branch just south of New Washington is the following section:

Crystalline gray limestone	4 feet.
Drab fetid fine-grained limestone	18 feet.
Yellow clay shale	3 feet.

The drab limestone seems to correspond to the limestone described in the preceding paragraphs and the yellow shale possibly represents the Waldron shale.

In the south corner of section 214 there is this exposure:

New Albany black shale	5 to 20 feet.
Cement rock	8 to 10 feet.

The cement rock shows thin white streaks which contain *Chonetes yandellanus, Fenestella, Spirifer granulosus*, etc.

In the east corner of section 196, the cement rock with a thickness of seven feet, is overlain by shale and underlain by shaly limestone. The upper four feet of the cement is a drab impure rock carrying *Chonetes yandellanus, Stropheodonta hemispherica, Spirifers*, and a Trilobite.

Fetid limestone, overlain by chert and containing many *Chonetes yandellanus,* outcrops on the New Market-Washington road 200 yards west of the bridge over Fourteen Mile Creek, and probably represents the cement rock.

Cement rock crops out a few feet in thickness at different places along the West Fork of Fourteen Mile Creek to Justice postoffice, where the following section is had:

	Ft.	In.
Till and drift	0 to 8	0
New Albany black sheety shale	2	0
Bluish gray crystalline limestone	1	6
Iron ore	0	3
Cement rock	8	0
Shaly limestone	4	0

Scott County.

The cement rock crops out in the West Fork of Fourteen Mile Creek on up to the village of Chelsea. The limestone towards the northeast becomes much more impure and argillaceous, and is tougher and does not break with a conchoidal fracture, as may be seen where the road leading south from Chelsea postoffice crosses the tributaries of Fourteen Mile Creek.

The eastern limit of the Sellersburg limestone traverses the flat ridge to the east of Chelsea, which is covered with a depth of from 12 to 40 feet of soil and drift. Outcrops do not occur, so the distribution must be gotten from well sections which distinguish only between shale and limestone. The line as laid down on the map is from such data.

Lexington and Vicinity.—One mile east of Lexington, in the south bluff of Town Creek, in the northeast quarter of the northwest quarter of section 2, township 2 north, 8 east, the cement shows five or six feet in thickness, overlain directly by the Black shale and underlain by shaly limestone in the bed of the branch. Five hundred yards down the creek toward Lexington the ledge has increased in thickness to seven feet.

Opposite the B. & O. S.-W. depot in Lexington this section occurs:

	Ft.	In.
Soil	2	0
New Albany black shale	10	0
Ferruginous conglomerate	0	3
Heavy ledge crystalline limestone	2	0

The conglomerate consists of black pebbles, like those described from the bottom of the Sellersburg limestone, with coarse sand, all imbedded in a matrix of solid bright iron pyrites. The cement rock is concealed at this place.

A section at the pike quarry at the north corner of the town of Lexington is as follows:

	Ft.	In.
New Albany black shale	5 to 10	0
Blue crystalline limestone	2	6
Cement rock	5	0
Gray crystalline limestone (Jeffersonville)	15	0

A mile northwest the overlying limestone thickens up to five feet, but soon dips below the level of the creek and disappears.

Woods Fork.—Just below where the road crosses Woods Fork in the northeast quarter of section 28, township 3 north, 8 east, this section is exposed:

	Ft.	In.
New Albany black shale......6 to	8	0
Conglomeritic iron ore......	1	0
Heavy crystalline limestone......	5	6
Cement rock, fair looking......	0	8
Shaly limestone with *Stropheodonta demissa*......	4	0

At a spring house in the northeast quarter of the southeast quarter of section 21, township 3 north, 8 east, the exposure is as follows:

	Ft.	In.
Soil and drift......	4	0
New Albany black shale......	6	0
Massive crystalline limestone......	3	0
Blue argillaceous cement rock......	1	2
Heavy crystalline limestone......	6	0

Where the road crosses Woods Fork in section 15, same township, 3 north, 8 east, blue cement rock four inches thick is exposed, overlain by four feet of crystalline limestone, and that in turn by Black shale. On the north side of the same creek the cement is underlain by twelve feet of Jeffersonville limestone with *Chonetes yandellanus*, *Stropheodonta hemispherica*, *Stropheodonta demissa* and a *Spirifer*.

At the forks of the road 400 yards south of the northwest corner of section 25, township 3 north, 8 east, a foot of yellow calcareous shale outcrops, overlain by five feet of crystalline limestone.

In the northeast quarter of the southwest quarter of the same section two feet of characteristic cement rock shows, overlain by three feet of crystalline limestone and underlain by 10 feet of Jeffersonville limestone.

Near the center of the same section the drab cement rock outcrops three feet in thickness, overlain by two feet of hard blue limestone with *Tropidoleptus carinatus*.

In the southwest quarter of the northeast quarter of section 20, township 3 north, 8 east, the cement rock is represented by 12 inches of fetid limestone overlain by 2 feet of crystalline limestone.

In the northwest quarter of the northwest quarter of section 24, township 3 north, 8 east, the cement is represented by a clay parting between nine feet of crystalline limestone above and 15 feet of similar limestone below.

Hog Creek.—Near the center of section 14, township 3 north, 8 east, the cement, represented by a thin clayey stratum, is overlain by 12 feet of crystalline limestone.

Where the road crosses Hog Creek in the southeast quarter of section 15, township 3 north, 8 east, four to 12 inches of cement rock is overlain by four feet of crystalline limestone and that in turn by shale.

In the bluff along the creek in the southwest quarter of the same section we have this exposure:

	Ft.	In.
New Albany black shale	2	0
Flaggy crystalline limestone	4	0
Fetid buff cement rock	0	8-10
Crystalline limestone (Jeffersonville)	15	..

Near the B. & O. Railway in the northeast quarter of section 20, township 3 north, 8 east, the cement a foot in thickness is overlain by crystalline limestone 30 inches in thickness.

Going up a drain in the northwest quarter of section 16, township 3 north, 8 east, the cement thins to three or five inches, then to one or two inches, and then thins out completely, and this is the most northerly extension of the cement rock as a persistent bed.

II. TOPOGRAPHY.

In general the topography of the region with which we are concerned is that of a dissected plateau sloping gently toward the west, where rises the sharp escarpment of the bold range of Knobs. The slope of the surface of this plateau is very nearly that of the underlying limestone, especially in the region lying between the Pennsylvania and B. & O. railways from Otisco to Jeffersonville and Memphis. The tops of the flat ridges in this region are covered with the New Albany Black shale, beneath which outcrop the Sellersburg and Silver Creek limestones. The streams cut down into the Jeffersonville limestone, and those flowing to the southwest keep along in the same horizon, the fall of the stream being just about equal to the dip of the rock. On the western side of the plateau, as the Knob escarpment is approached, the Black shale increases in thickness and begins to make a more rolling topography. But in the region to the east, lying between Charlestown, Otisco, Lexington and the Ohio, where the Black shale is thin or entirely wanting, the country is flat as a floor, but trenched here and there by streams. At the river bluffs it

pitches off abruptly in an escarpment about 400 feet in height. The country southeast and east from Watson is flat and the trenches cut by the streams are invisible a short distance away, so that the topography has every appearance of being in a youthful stage, probably post-glacial. But wells on these flats show 10 feet of soil and clay without drift, apparently indicating that the region has not been occupied by the ice. Unmistakable till and drift occur, however, in the neighborhood of Charlestown, on the hill just south of Speed's new quarry, in the eastern part of section 131, and in the south corner of section 168, as well as in other places. One mile west of Sellersburg on the road to Hamburg there is beside the road an outcrop of four to five feet of gravel embedded in a sandy clay strongly resembling till. The gravel consists of rounded sandstone, knobstone and quartz pebbles, ranging up to one inch in diameter, although the quartz pebbles rarely exceed one-quarter inch in diameter. Mixed with these are angular fragments of chert, limestone and sandstone.

From these deposits and from the glaciated aspect of the country in certain sections, as well as for reasons which will appear later, we think that the whole region, west as far as Silver Creek and south as far as Jeffersonville, was occupied by an ice sheet which left its impress on the soft Black shale topography without leaving a great amount of drift. No evidence of buried channels has been found, with the exception of that thought to indicate an old channel of the Ohio. If the topography is post-glacial, the preglacial topography must have existed in the Black shale and have been carried away entirely by the ice. We find no evidence that this region has been occupied by the great Collett Glacial river as has been urged.*

PLEISTOCENE TERRACES.

The Flatwoods.—In the sketch map opposite the dotted line represents the edge of the Paleozoic rocks, and the broken lines, numbered from I to IV, represent the terraces. Lying between the Paleozoic border and the upper terrace, or No. 1, and occupying the greater part of sections 32, 33, 45, 46 and 47, is a region called the Flatwoods. It is almost level, sloping very gently to Silver Creek on the northwest. Along the southern edge it rises slightly higher and is slightly irregular, having higher hummocks of sand. Where it first starts from the Paleozoic this terrace is about 40 feet above Terrace No. 3. But after Terrace No. 2 puts off from it in the east part of section

* Geological Survey of Indiana, 1881, p. 60.

31, it stands but 10 or 15 feet above that terrace and seems finally to die away in a series of hummocks before reaching Silver Creek. The

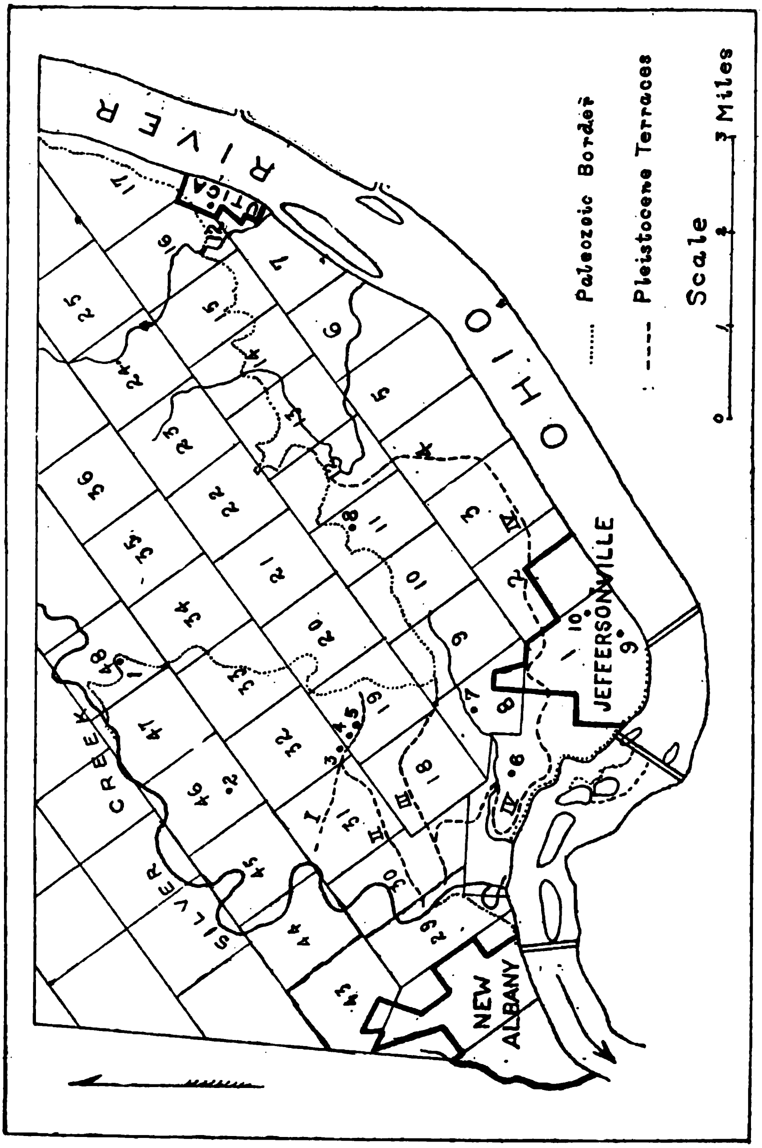


Fig. 71. Pleistocene Terraces in the vicinity of Jeffersonville and New Albany.

impression is unavoidably forced upon one that this was a spit which projected out from the Paleozoics and was gradually built up into a bar which closed the bay occupied now by the Flatwoods and allowed

that to fill up with sediment. The wells in the Flatwoods region seem to bear out this conception.

Well No. 1, in the engine room of the Silver Creek Cement Co.'s mill is reported to go 190 feet through black, mucky, slimy, stinking clay, striking gravel, but no bed rock. It seems probable that there is an error in the reported depth of this well, though it must be of more than ordinary depth. It lies in a recession of the Paleozoic border, and any unusual depth without striking bed rock can only be explained on the supposition that the bore was put down in an old buried valley. But it is difficult to explain a valley 190 feet in depth at this point, when the Ohio scarcely reached any such depth. It is our conception that this well struck the valley of some small stream emptying into this bay when it was at a level something like 90 or 100 feet lower than now. More well sections are needed to show this, however.

Well No. 2. A well was put down 60 feet here in the middle of the Flatwoods, which struck clay and sand, but no rock.

Well No. 3, on Mr. Stacy's place, struck potter's clay at 14 feet and went through 42 feet of this, interbedded with sand.

Well No. 4, at John Yarborough's, shows 46 feet of sand.

Well No. 5, James D. Applegate's, has 53 feet of sand and clay.

A well in the east corner of section 32 struck logs and sticks at 20 feet.

Terrace No. 2 puts off from No. 1 near the east corner of section 31 at an elevation some 10 feet below it and 30 feet above Terrace No. 3, and is similar as regards structure to Terrace No. 1. No well sections were obtained upon this terrace.

Terrace No. 3.—This terrace starts as a spit-like projection from the southernmost extension of the Paleozoic in the vicinity of the cemetery one mile north of Jeffersonville, bears north of west one mile, then turns south of west and crosses Silver Creek at the bridge on the New Albany and Charlestown pike. It is about 20 to 25 feet above Terrace No. 4, has the beach ridge formation in front, sloping gently back to the base of the terrace above it. No well sections were obtained in this terrace.

Terrace No. 4 leaves the Paleozoic upland near the middle of section 12, bears south to within a quarter of a mile of the Ohio, then southwest parallel to the river for a mile, thence west through the north edge of the city of Jeffersonville, striking the river in the vicinity of Howard Park, a suburb of Jeffersonville, just east of the old village of Clarkville, follows the river for a mile, then turns north and joins Terrace No. 3 in the southern part of section 30.

This terrace is about eight or 10 feet above high water mark of 1884, and 15 or 16 feet above the flood plain, which was overflowed six to eight feet in 1884.

Well No. 6, in Howard Park, passed through bluish to yellowish mottled clay for 20 feet, then sand and gravel for 25 feet.

Well No. 7 struck rock at the depth of 40 feet.

Well No. 8, at Henry Mahanda's, soil and clay 40 feet, gravel five feet. Bed rock is probably not far below. This would put it at or below the level of low water in the Ohio.

All these terraces are continued down the river beyond Silver Creek, but beyond that point they have not been examined by the writer. It is to be hoped that in the future opportunity may offer for a more comprehensive study of these terraces which have such a direct connection with the Pleistocene history of this region.

A PREGLACIAL CHANNEL OF THE OHIO.

Mr. John Bryson was, so far as the writer is aware, the first to suggest,* though without much reason for so doing, that the Ohio had a preglacial channel to the north of the present channel. Certain facts that have come under the observation of the writer seem to bear out that view, though far from demonstrating it, and leaving much to be determined in the future. Attention was called above to the section of *Well No. 6,* in Howard Park, where no rock was found at a depth of 45 feet, presumably about the level of low water in the Ohio River. Yet sections by Professor Borden and the writer at the old Beach Mill on the river bank just opposite the site of the well show a thickness of 25 to 35 feet of limestone above low water mark. And these rocks continue to outcrop all the way up the river to the Louisville and Jeffersonville bridge. This indicates a rim of rock along the river and a basin or valley behind.

The First National Bank building of Jeffersonville is located about two blocks from the river. The foundation is reported to rest on solid bed rock at a depth of 15 feet, while *Well No. 9,* 15 feet away, struck the limestone at 35 feet. *Well No. 10,* at the corner of Mechanic and Chestnut streets, about a quarter of a mile north of *No. 9,* went 80 feet before striking bed rock. This would make the level of the rock some 40 feet below the reef at the falls. *Well No. 12,* at Mr. Biggs', in Utica, went 120 feet, all in gravel. The bottom of the well must be 80 feet below the level of low water in the Ohio. This, of course, indicates nothing more than that the preglacial channel of the Ohio was at least 80 feet deeper than it now is.

*American Geologist, Vol. V, 1890, pp. 186-188.

It has seemed to us possible that one of the preglacial branches of the Ohio left the present course of the river about Utica, flowed along the bottom skirting the edge of the Paleozoic upland to the neighborhood of Jeffersonville, then turning northward made an oxbow bend out through the Flatwoods, re-entering the Ohio between Clarksville and the mouth of Silver Creek. A serious objection to this view seems to be encountered in the record of *Well No. 7*, which struck rock at 40 feet, right where one would expect the deepest part of the hypothetical channel. Nevertheless, it seems necessary to employ the Ohio to perform the excavation which took place prior to the formation of the Flatwoods. Certainly Silver Creek would be unequal to the task, running as it does over a rock bottom just before it enters the Flatwoods, and at a level not more than 20 feet below that of the Flatwoods.

If the Ohio once moved out through the region of the Flatwoods at a level much below this present level, then back in a narrow defile, the predecessor of Silver Creek pouring over the limestone wall might give us the deep gorge which later became filled with blue mud, as shown in the section of *Well No. 1* as given above.

If such were the case, the river must have been dispossessed of this channel by the advancing ice sheet. Deprived of this deeper channel, the Ohio must have flowed at a much higher level at some later time, before it found its present course over the reef at the Falls. The interval in which it flowed at the higher level was contemporaneous with the formation of the terraces.

III. ECONOMIC GEOLOGY OF THE SILVER CREEK HYDRAULIC LIMESTONE.

Texture and Composition.

In texture the cement rock is a very fine grained limestone, the grain being so fine as to require a good hand lens to distinguish it. It is usually without traces of stratification and occurs massively, breaking with a sub-conchoidal fracture. In some of the quarries, however, the ledge is divided horizontally by bedding planes into two or more ledges which in places are reported to have different values for cement. The universal practice, however, is to take the workable ledge from top to bottom as it comes, giving a uniform quality to the product. Where the cement rock is fossiliferous, as it commonly is, the fossils, bryozoa especially, show roughly by their position the planes of their deposition.

Impurities are comparatively rare in this formation. The upper part of the ledge sometimes contains "blotches" of white appearance, consisting of calcareous or siliceous material. The fossils are sometimes solidified. Minute crystals of iron pyrites are sometimes disseminated through the rock.

The color in the freshly exposed rock ranges from light drab through dark drab to bluish drab. On the weathered surfaces it shows buff. The fossiliferous streaks are generally darker.

The chemical composition shows the rock to be magnesian argillaceous limestone with a mixture of more or less ferric iron. Two of the analyses of Rosendale stone show quite a percentage of calcium sulphate, but this is possibly an error of analysis, or a local development.

The appended table gives analyses of six Indiana cement limestones, seven New York cement limestones, three of the Milwaukee and one from Illinois, each with the properly accredited authority:

CHEMICAL ANALYSES OF HYDRAULIC LIMESTONES.

	LOCALITY.	Calcium Carbonate $CaCO_3$.	Magnesium Carbonate $MgCO_3$.	Silica SiO_2.	Ferric Oxide Fe_2O_3.	Alumina Al_2O_3.	Oxide of Manganese Mn_2O_3.	Potassa and Soda K_2O and Na_2O.	Lime CaO.	Magnesia MgO.	Calcium sulphate $CaSO_4$.	Organic, Water and Undetermined.	Total.	Authority.
1	Silver Creek, Indiana, "Ohio Valley"	54.31	16.90	18.33	1.67	4.98			0.14	0.33		1.19	97.85	W. A. Noyes, Analyst.
2	Silver Creek, Indiana, "Black Diamond"	51.95	32.97	9.69	1.95	2.77			0.10	0.11		0.36	99.90	W. A. Noyes, Analyst.
3	Silver Creek, Indiana, "Belknap's Falls City"	52.50	[illegible]5.09	9.80	1.40	2.03			0.04	0.11		0.47	101.44	W. A. Noyes, Analyst.
4	Silver Creek, Indiana, "Speed's"	61.70	16.74	13.65	1.45	3.46			0.15	0.25		0.45	97.85	W. A. Noyes, Analyst.
5	Silver Creek, Indiana, "Hausdale"	60.69	15.90	15.21	1.44	4.07			0.07	0.32		0.86	98.56	W. A. Noyes, Analyst.
6	Rosendale, Ulster County, N. Y	45.91	26.14	15.37	11.38							1.20	100.00	Mineral Industry, Vol. I, 1892, p. 49.
7	Rosendale, Ulster County, N. Y., "Light"	50.82	17.74	22.66	2.39		0.55	Tr.			4.37	1.39	100.00	Mineral Industry, Vol. I, 1892, p. 49.
8	Rosendale, Ulster County, N. Y	44.34	23.92	22.14	3.80		0.88	Tr.			3.94	0.83	99.85	Mineral Industry, Vol. III, 1894, p. 90.
9	Rosendale, Ulster County, N. Y	46.00	17.76	27.70	1.26	2.24		4.02					99.08	Geological Survey of Indiana, 1873, p. 120.
10	Rosendale, Ulster County, N. Y	45.54	25.94	15.37	2.25	9.13						1.20	99.43	Mineralogy of New York, L. C. Beck, p. 78.
11	Chittenango, Madison County, N. Y	44.64	37.44	11.76	1.50	2.73						1.50	99.57	Mineralogy of New York, L. C. Beck, p. 80.
12	Chittenango, Madison County, N. Y	48.40	34.30	13.85	1.75							1.70	100.00	Mineralogy of New York, L. C. Beck, p. 80.
13	Milwaukee, Wisconsin	45.54	32.46	17.56	3.03	1.41							100.00	
14	Milwaukee, Wisconsin	48.29	29.19	17.56	2.24	1.40							98.68	Trans. A. I. M. E., Vol. VIII, p. 507.
15	Milwaukee, Wisconsin	41.34	34.88	16.99	1.79	5.00							100.00	
16	Utica, Illinois	42.25	31.98	21.12	1.12							1.07	97.54	Mineral Industry, Vol. I, 1892, p. 49.
17	Louisville, Kentucky	50.43	18.67	25.78		2.93		.45					98.25	Geological Survey of Kentucky, Vol. II, 1857, p. 220.

Inasmuch as the first five analyses in the foregoing table have been somewhat recast to make them harmonize with the other analyses, the official report of Professor Noyes to the State Geologist is here inserted.

ROSE POLYTECHNIC INSTITUTE,
TERRE HAUTE, IND., January 16, 1900.

Prof. W. S. Blatchley:

Dear Sir—I have analyzed the samples of hydraulic limestone left with me in October last with the results given below.

The labels were:

No. 1. Ohio Valley Quarry, n. e. cor. sec. 34, Clark's Grant.
No. 2. Speed's Quarry, sec. 132, Clark's Grant.
No. 3. Belknap's Quarry, sec. 89, Clark's Grant.
No. 4. Black Diamond Quarry, s. e. cor. sec. 66, Clark's Grant.
No. 5. Hausdale's Quarry, sec. 149, Clark's Grant.

	1. Ohio Valley.	2. Speed's.	3. Belknap's.	4. Black Diamond.	5. Hausdale's.
Insoluble in hydrochloric acid ..	25.90	18.68	12.75	13.03	21.26
Lime (CaO), soluble in acids.....	30.41	34.55	29.40	29.06	33.99
Magnesia (MgO), soluble in acids	8.48	7.97	16.71	15.70	7.57
Ferric Oxide (Fe_2O_3), soluble in acids	0.47	0.43	0.85	1.15	0.39
Alumina (Al_2O_3), soluble in acids	0.27	0.30	0.25	0.80	0.32
Loss on ignition..........	33.46	36.65	40.47	39.29	35.16
Total	98.99	98.58	100.43	99.05	98.69

The results of the analysis of the insoluble portion and the composition, on the supposition that the soluble lime and magnesia are in the form of carbonates, are as follows:

	1. Ohio Valley.	2. Speed's.	3. Belknap's.	4. Black Diamond.	5. Hausdale's.
Soluble portion— Calcium Carbonate ($CaCO_3$)....	54.31	61.70	52.50	51.95	60.69
Magnesium Carbonate ($MgCO_3$)	16.90	16.74	35.09	32.97	15.90
Ferric Oxide (Fe_2O_3)..........	0.47	0.43	0.86	1.15	0.39
Alumina (Al_2O_3)	0.27	0.30	0.25	0.80	0.32
Insoluble portion— Silica (SiO_2)	18.33	13.65	9.80	9.69	16.21
Ferric Oxide (Fe_2O_3)	1.20	1.02	0.55	0.80	1.05
Alumina (Al_2O_3)	4.71	3.16	1.78	1.97	3.75
Lime (CaO)	0.14	0.15	0.04	0.10	0.07
Magnesia (MgO)..........	0.33	0.25	0.11	0.11	0.32
Undetermined	1.19	0.45	0.47	0.36	0.86
Total	97.85	97.85	101.44	99.90	98.56

For greater simplicity the iron is all put down as ferric oxide, though a part of it is in the ferrous state and the soluble portion is probably mostly in the form of ferrous carbonate ($FeCO_3$). The part of the insoluble portion recorded as "undetermined" probably consists mainly of alkalies.

The high footing of No. 3 is probably due to the presence of some soluble compound of "lime" or "magnesia" other than the carbonate. See the other footing for the same analysis.

W. A. NOYES.

QUARRYING.

Stripping.—Two methods of stripping off the earth preparatory to quarrying are practiced; and since the earthy covering may range from a few inches to 10 or 15 feet, the most economical method for the case in hand is quite a desideratum. The first method, and the one usually followed in the smaller quarries and in those larger quarries where the stripping is light, is the ordinary one of plows and scrapers operated by horse power. An improved method, which is followed at Speed's quarry and at some of the larger concerns operating open-wall quarries, is to prepare to strip a large area at once by laying down a temporary track along one side of the area, upon which track is placed a common hoisting engine with large drum and cable. The earth is loosened by large plows which are drawn by steam across the area to be stripped, and returned by a single horse. The same method is pursued with the large wheel scrapers, which, when loaded, are drawn by horses to the dumping ground. The final cleaning up must be done with shovel and wheelbarrow.

With regard to the rock stripping, the ordinary methods of blasting and carting are used. In some cases the rock stripping is crushed and used for road metal or railway ballast. The Black shale has also had a limited employment for such purposes.

Blasting and Loading.—When the cement ledge has been stripped it is then ready for quarrying and transportation to the kilns. An electric system of blasting is employed in the larger quarries. Holes are drilled with steam drills at intervals of several feet and charged with dynamite, which is exploded simultaneously by means of a pull-up electric battery. Such of the rock as is less than six to 12 inches in its largest dimension is ready to go directly to the kilns, but all larger than that must be made smaller with a sledge hammer. In the majority of cases the quarry is in juxtaposition to the line of kilns. An inclined track leads from the quarry up to the top of the line of kilns and passes across their open tops. Up this track is brought the limestone and coal. At the foot of the incline

is a small turntable, and from this tracks lead to the coal pile and to those parts of the quarry where the work is active. The cement rock is loaded upon small iron dumping trucks; these may be made into trains and hauled by a horse to the turntable, if far distant, but usually are pushed by hand. They are pulled one at a time up the incline by a hoisting engine at the top of the incline, and pushed along by hand to the proper kiln.

Speed's quarry is situated about a mile and a half from the mill and connected with it by a steam tramway. A small locomotive draws a train of small flat cars. The quarry is so arranged that a long face is being worked at once. Parallel to this and at a convenient distance is a temporary track on which is a traveling crane. The temporary track of the tramway parallels this at the right distance. The rock is loaded upon a square flat box with a bail attached. By means of this bail the box is lifted by the crane and placed on one of the flat cars and an empty box put in the place of the full one at the quarry face. Having arrived at the mill the boxes are emptied into the crusher, which reduces the rock to the proper size for burning, doing away with the expense of breaking large pieces by hand in the quarry.

Mining.

Mining or tunneling has usually been resorted to when the stripping became so heavy as to render further open quarry work unprofitable, but in a few instances, notably at the new Banner and Hoosier mills, and others, tunneling has been the order from the start. In the latter instance a pit large enough to give room for the turntable and the slope of the incline has been dug through the New Albany Black shale, the Sellersburg limestone and the cement ledge. From this pit entries are driven in any direction desired. It may be noted here that the Banner Co.'s opening is near the east side of their property and the major part of their tunneling will have to be to the westward. Now the natural dip of the rocks over this whole region is to the west. Since the cement ledge here lies at or near the level of Silver Creek, it will be strange if water does not follow down the entries and rooms and collect along the working faces, to the great trouble and vexation of the miners. Probably a much better plan would be to locate the opening or shaft near the western side of the property and work the rooms eastward against the dip, allowing them to drain themselves into a sump at the shaft where the water can be easily handled.

Attention might at this place be directed to the fortunate stratigraphic relation of the cement rock, overlying the limestone and shale, which makes possible tunneling and long wall mining in a limestone formation with no greater thickness of roof than is usually found in this district. Were the roof either all limestone or all shale, mining would not be possible. In the former case the limestone would be cut up in two directions by a network of seams, caused by the solution of percolating waters along the joint cracks, and would, of course, not be capable of self-support over rooms 100 feet square, as are worked in this region. It is only because the covering of impervious shale acts as a roof and sheds off the underground water, that the limestone has remained unaffected. Further, were the roof of shale alone, its strength would not be sufficient to sustain roofs of the size described; draw slate would be continually falling, and some of the slate would come away with the limestone, necessitating hand sorting, all making operation more expensive.

The method of mining, briefly, is as follows: At some side of the quarry, where the roof is thick enough to be suitable (generally in practice where the stripping is too deep for profitable open quarrying), single entries are driven into the ledge from 20 to 40 feet in width and at an equal distance apart. Once back in the ledge all the stone is taken away excepting pillars 10 to 15 feet square and 40, 50, 60, or even 100 feet apart. The entries and rooms are lighted with electric arc lights and ventilated by air escaping from the compressed air drills. The rock is shot down, just as in coal mining, except that "under-mining" by either pick or machine is unnecessary. Holes are bored by an Ingersoll rock drill driven by compressed air, and mounted on an upright bar which, by means of a jack-screw base, can be braced between the roof and the floor of the mine.

From 35 to 40 charges of powder are put in and discharged by a pull-up electric battery. This will bring down rock sufficient to make from 150 to 200 barrels of cement. Charges are usually fired at the noon hour and just before leaving in the evening, giving the rock a chance to all get down without interrupting work.

The rock may be reduced to the proper size for calcining by hand or by crushing, just as in open quarrying. It is then loaded on self-dumping cars, varying in design and size with the different works, and drawn to the kiln by horse or steam power.

Ulster County Methods.—With one exception all the plants engaged in hydraulic cement manufacture in the famous Rosendale District of Ulster County, New York (producing about one-half of

the total product of the United States), raise the rock by mining rather than by quarrying.* The region is one of violent folding and faulting, rendering mining unavoidable. The mines are worked on the slope and the location so chosen that the head of the slope is on a level with the top of the kilns. The slopes preclude hand or horse haulage and necessitate rope haulage, involving the erection of elaborate rope haulage plants. When sudden changes of dip occur it necessitates independent haulage stations and grading of tracks. Of necessity the entries and rooms must be driven with the dip, requiring close attention to pumping the water away from the working face. As yet the water has not interfered to any serious extent. The greatly increased cost of production entailed by the dipping of limestone is counterbalanced by proximity to markets, and cheap transportation for fuel and product furnished by the Delaware and Hudson Canal and competitive railroads. The great sale of Rosendale cement has ensued from its early occupation of the market and its proximity to the great populous centers of the East.

Calcination.—As noted before, the cement rock may be reduced to kiln size by hand at the quarry or may be crushed at the kilns in a Blake or some similar form of crusher. It then goes to the kilns. The kilns are uniformly ordinary continuous up-draft kilns. In the older plants they were arranged in a line, and surrounded by a solid masonry wall. The later plants have kilns of cylindrical sheet steel resting on a masonry foundation. When ten or more kilns are in use it is customary to arrange them in two parallel lines with the draw doors facing the track between, which leads to the mill. Both kinds are lined with fire brick. The kiln draws together near the bottom and is closed by several grate bars, with a room beneath to receive the iron car into which the calcined cement is drawn. The kiln is charged with a kindling charge of wood and coal, upon which is dumped cement rock and coal in the proportion of two loads of rock to one of coal until the kiln is filled. The fire is lighted, and as the charge sinks with the consumption of fuel more coal and stone is added, always keeping the kiln full. At the end of about 72 hours' burning the lower part is ready to draw. This process is kept up continuously, drawing from the bottom and adding at the top, the passage from the top to bottom taking about 72 hours.

Grinding.—The loaded cars of calcined cement go up an incline and as the rock is dumped into the hopper of the coarse crusher, a man stands ready here with long tongs and picks out all "green" and overburned stone. The green stone is sent back to the kilns, the

* New York, 13th Rep. State Geol., Vol. I, pp. 379-384.

overburned or "clinker" carted away. The product from the coarse crusher passes over a screen and about one-half is fine enough to go through, which part is fit for cement and goes directly to the barrels. The tailings go next to the re-grinder, a coffeemill arrangement with steel cones. The product passes over a screen of the same mesh as that following the coarse crusher. About one-third of the product goes through and goes to the barrel. The tailings go to the buhrs. The product of the buhrs goes through a screen of the usual mesh and four-fifths passes through and goes to the barrels. The other one-fifth is returned to the buhrs. The buhrs are constructed like ordinary buhr mills, except that the grinding surface is of rock emery instead of French buhr. Formerly Catskill granite (?) was used for the grinding surface, but the wear on each stone was about one-fourth inch per day, sufficient to obliterate the dress, and require re-dressing every night. The life of such a stone was but a single season, whereas the rock emery stones wear but one-sixteenth of an inch on each stone per month, and the life of the stone is eight or 10 years. The emery has consequently displaced the other stone.

The usual arrangement of grinding and screening machinery is as follows: One screen for each two coarse crushers, one for each re-grinder and one for each two sets or "run" of buhrs.

Double break roller mills were tried at the Speed mill, but were found unsatisfactory and the buhrs replaced. The first break was corrugated and the second break was smooth, and all the rolls were run at the same speed.

The new Banner mill now being erected (September, 1898) is putting in Griffin grinding mills. The proprietors have great hopes that these mills will reduce the number of re-grindings and boltings necessary to bring the cement to the proper fineness. It is claimed that these mills will take the product of the coarse crushers direct and reduce 95 per cent of it to the standard fineness. If so it will effect an appreciable saving in the cost of production.

Other forms of grinding mills which are coming into vogue are the Williams mill and the Clark mill. These are generally used to replace the re-grinders, that is, take the product from the coarse crusher and pass it on to the Griffin mill, which takes the place of the buhr in finishing the product.

The cement as it comes from the grinders is sometimes hot enough to set fire to the wooden conveyors and elevator boxes, though they are lined with sheet iron.

From the mill where the cement is packed in barrels or paper bags, it goes to the stock house. The favorite plan is to have the

quarry, the kilns, the mill and the stock house in a line, along one side of which runs the railway switch, ending at one edge of the quarry where the coal dump is situated. The cooper shop, a necessary adjunct, is generally situated on one side with a chute for the barrels leading into the packing room. The course of the cement from quarry to stock room is graphically shown in the following flow sheet:

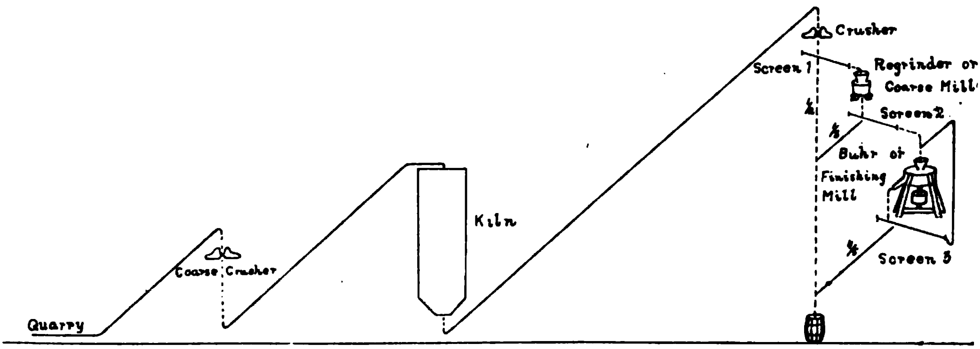


Fig. 72. Flow Sheet of a Typical Cement Plant.

Testing.—For testing fineness a convenient apparatus consists of a small sieve of the proper mesh and a glass tube holding perhaps one-half pint and graduated to 100 parts. This tube is filled even with the ground cement and emptied into the sieve and shaken until all has gone through that will. The remainder is poured into the tube and its percentage of the whole read. This subtracted from 100 gives the per cent. of fineness.

When the tests to determine the value of stamp sand and standard sand in mortars were made, the results of which are given in a table on a following page, tests of the fineness were also made, and the results are given in the following table. The first column gives the percentage of the whole mass of that part of the cement which passes through a sieve having 2,500 meshes to the square inch. The second column giving the percentage with a mesh 6,400 to the square inch. The last column gives the percentage with a mesh 10,000 to the square inch.

TABLE OF FINENESS OF CEMENTS.

Name of Cement.	*1.*	*2.*	*3.*
Portland	96%	87%	84%
Buffalo	84%	76%	74%
Akron	95%	85%	82%
Louisville	84%	75%	72%
Rosendale	94%	92%	89%

For testing strength a Fairbanks testing scale is used. The cement is mixed "neat," that is with water alone, and moulded into "∞" shaped briquettes which give a cross-section of one square inch in the middle. These are allowed to "set" varying lengths of time. The clamps of the scale are then adjusted to the ends of the test briquette and the sliding weight moved out the scale arm until the briquette is pulled apart. The scale arm will show the number of pounds weight it has sustained.

During the year 1894 a series of tests was instituted under the direction of Mr. Edward Kidwell to demonstrate the truth or falsity of the prevalent belief that "sharp" sand, as that from a stamp mill, will make a much stronger mortar than that made with ordinary waterworn quartz sand.

The results as given,* though somewhat contradictory, show in the total an increase of over 50 per cent. in tensile strength of mortar made with stamp sand as compared with that made with standard sand. Incidentally the table gives sufficient data for a comparison of the strength and value of five of the most used cements in the United States. A reproduction of some of the more essential points is given in the following table. The briquettes and cubes were mixed, immersed and tested, with the water and air ranging about 65 to 70 degrees. For each test of tensile strength six briquettes of standard size were made, and for each test of compressive strength two one-inch cubes were made. Tests were made both for seven days' immersion and 28 days' immersion of neat cement, of a 1—1 composition of cement and standard sand and of a 1—1 composition of cement and stamp sand. In the table which follows only the averages of the six briquettes and the two cubes have been taken. In the first column the amount of water used in the briquettes is given, and in the other columns the average pounds per square inch of tensile or compressive strength of the specimen tested.

*Mineral Industry, Vol. III, 1894, pp. 95-96.

TABLE OF CEMENT TESTS, INVOLVING TENSILE STRENGTH AND CRUSHING STRENGTH.

NAME OF CEMENT.	Record of 7-Day Tests.			28-Day Tests.	
	Per Cent. Water.	Tensile Strength.	Compressive Strength.	Tensile Strength.	Compressive Strength.
Neat Cement.					
Portland	29	368.8	1,483.5	506.4	2,000
Buffalo	33	107.6	691.5	260.3	1,320.5
Akron	33.5	45.4	328	137.5	629
Louisville	38	81.3	403	130.5	619.5
Rosendale	38	44.5	188.5	108	377
1 Part Cement to 1 Part Standard Sand.					
Portland	20.6	213.6	1,152.5	311	1,980
Buffalo	21	46.6	280	131	532.5
Akron	19	47	157	69.6	375
Louisville	26	37	240	68.5	235.5
Rosendale	23	15.6	108	84.8	264
1 Part Cement to 1 Part Stamp Sand.					
Portland	14.5	223.5	1,587.5	415	2,000
Buffalo	20	55.5	322	167.1	1,117.5
Akron	18.5	45.1	222.5	82.3	468.5
Louisville	22	41.5	235	102.8	469.5
Rosendale	21	14.6	134.5	72	325

Portland made by Brooks, Shookridge & Co., Grays, Essex, Eng.
Buffalo made by Buffalo Cement Company, New York.
Akron made by Cummings Akron Company, Akron, N. Y.
Louisville made by Falls City Cement Company, Louisville, Ky.
Rosendale made by Newark and Rosendale Cement Company, New York.

Transportation.—All the cement mills of this region are located upon one or the other of the two railroads, the Jeffersonville division of the B. & O. Railway, or the Jeffersonville branch of the P., C., C. & St. L. Railway, and have adequate transportation facilities. The latter road has a local freight train which does nothing but make up the cement business.

Capacity.—The 13 plants in Indiana which were active in 1900 operated 116 kilns, having a daily capacity of 16,000 barrels, or 5,000,000 annually. The production for 1900 was 2,512,000 barrels, showing that the plants are taxed but one-half of their capacity. Most of the plants have been in associations which prorated the orders. Some firms have bid up the quota of other firms year by year and thus some plants have been in operation most of the time while others were idle.

The production of cement for the Louisville district (14 plants in Indiana and 1 in Kentucky) for the years 1882-1889, inclusive, is taken from *Mineral Resources U. S.*

Year.	*Barrels.*	*Value.*	*Year.*	*Barrels.*	*Value.*
*1882	633,000	$696,300	1886	925,210	$782,428
*1883	820,000	820,000	1887	1,189,000	921,475
*1884	780,000	702,000	1888	1,214,000	880,150
*1885	800,000	640,000	1889	1,338,464	885,617

In the following table the first two columns are taken from *Mineral Resources U. S.*, the second two from *Rothwell's Mineral Industry* for comparison, and the last two were personally collected by the writer.

PRODUCTION OF HYDRAULIC CEMENT IN THE LOUISVILLE DISTRICT.

Year.	*Barrels.*	*Value.*	*Barrels.*	*Value.*	*Barrels.*	*Value.*
1890	1,533,579	$1,150,184	....	....	....	....
1891	1,513,009	983,456	....	....	....	....
1892	2,100,000	1,365,000	2,142,782	$964,252	....	....
1893	1,750,350	525,105	1,750,350	962,692	....	....
1894	2,000,000	800,000	2,225,000	1,057,500	....	....
1895	1,703,000	681,000	1,701,023	597,091	....	....
1896	1,636,000	654,400	1,434,337	504,049	....	....
1897	1,731,287	692,515	1,539,818	615,927	....	....
1898	2,040,000	816,000	1,929,018	482 254	....	....
1899	2,922,453	1,022,858	3,534,344	883,536	2,883,000	$518,940
1900	....	....	....	....	2,512,000	502,400

The grand total for the period, 1882-1900, inclusive, presents the very respectable figure of $15,001,481.

Associations.—The Union Cement Association was in existence in 1873 when Professor Borden reported on Floyd and Clark counties.† Each plant was apportioned a certain quota of cement to manufacture and overproduction and destructive competition were thus avoided. This agreement had elapsed in 1892, when the Western Cement Company was organized for like purposes. This association held out until 1898, when the competition of new, independent mills broke the established scale of prices, since which time has ensued a scramble for business in which profits have been lost sight of, and cement has been sold on the narrowest possible margin or on no margin at all.

The Union Cement and Lime Co. (D. Belknap & Co.), operating the Black Diamond mill and the Falls City mill in Indiana and the Black Diamond River mill in Louisville, and the Louisville Cement Co. (J. Speed & Co.), operating the Speed mill and the Queen City

* Estimated from production of Hydraulic cement in U. S. for those years.

† Geological Survey of Indiana, 1873, pp. 134-189.

mill in Indiana and the Hulme mill in Louisville, have preserved the organization of the Western Cement Company, and still do business under its regulations.

The Central Cement Company is an association of the Clark County Cement Co., the New Albany Cement Co., the Kentucky and Indiana Cement Co., the Banner Cement Co., and the Globe Cement Co. It has been in existence one year and has worked quite successfully.

The other mills act quite independently. At this writing (Jan., 1901) strong efforts are being made to effect an association of all the cement companies interested in the district.

FIRMS CONNECTED WITH THE CEMENT INDUSTRY.—Hydraulic limestone was first discovered in Onondaga County, in New York, in 1818, in connection with the construction of the Erie Canal, and the cement was thereafter used in the construction of the canal. Cement was first manufactured in Erie County in 1824, and in the Rosendale district in 1832.

The hydraulic limestone at the Falls of the Ohio was, curiously enough, first noticed in the construction of another canal, the Louisville and Shippingsport Canal, as has been noted on a preceding page, in the year 1826 or thereabouts, and used in the construction of all masonry work.

1.* *Beach Mill.*—A flouring mill, erected about 1832 at the village of Clarksville, by Lawson Verey, was later changed into a cement mill, and after passing through the hands of various owners came into the possession of Wm. F. Beach, who was operating it in 1873 when Prof. W. W. Borden made his survey for the report on Floyd and Clark counties.† At this time three kilns and two run of buhrs were in operation. The limestone was secured from the river bank adjacent by tunneling. The spring floods of the Ohio gave great inconvenience to the operation of tunnels, often flooding them completely. The formation of a trust and the purchase of the Beach Mill's quota by other firms allowed the mill to rust away in idleness until the flood of 1884 completed the destruction. To-day, but a pile of foundations marks the site of the pioneer of one of Indiana's most important industries. Professor Borden gives the following section at the quarry:

* The number refers to the number of the plant on the accompanying map.

† Geological Survey of Indiana, 1873, pp. 152-153.

	Ft.	In.
New Albany black shale	0	5
Crinoidal limestone	4	2
Hydraulic limestone, dark, with hornstone concretions	..	11
Hydraulic limestone	13	7
Corniferous	6	..
	25	1

The section of the river bluff near the old works obtained by the writer under the present unfavorable conditions is as follows:

	Ft.	In.
Heavy bedded bluish-gray limestone	3	0
Gritty limestone with black pebbles at base	2	6
Hydraulic limestone with chert and lime splotches	1	6
Hydraulic limestone	10	0
Shaly limestone with *Spirifer acuminatus*, etc	1	0
Massive shaly limestone	3	0
	21	0

2. *Gheen's Mill.*—A mill built by W. S. Hohn & Co. in 1868 near the center of section 48, Clark's Grant, has been operated by the Silver Creek Cement Co., producing the Silver Creek Brand of cement. In 1878 it became the property of C. W. Gheen & Co., the present owners. The original quarry was opened in the northeast corner of section 34, just west of the one now operated by the Ohio Valley Cement Co. In 1881 a quarry was opened in the creek bank upon the same section as the mill. When the stripping became heavy, tunneling was resorted to. Floods in the creek gave much trouble, however, and in 1892 a slope was driven to the hydraulic limestone nearer the mill and worked for about 300,000 barrels of cement. The last year in operation was in 1896. Its quota has been manufactured by the Falls City Cement Co., and the Ohio Valley Cement Co. In 1873 four kilns and two run of buhrs were in operation. At present there are eight kilns and four run of buhrs, having a capacity of 800 barrels per day.

A section of the older quarry by the creek is as follows:

	Ft.	In.
New Albany black shale	8	0
Heavy bedded encrinital limestone	6	0
Shale parting varying from 0 to	0	8
Encrinital limestone, lower 3 inches conglomeritic	1	0
Hydraulic limestone, few fossils, no "blotches"	8	0
Hydraulic limestone, concealed by creek	6	0

The black pebbles are distributed throughout a 2 to 3-inch sandy, gritty stratum, set off sharply in places from the underlying cement rock by a clay seam one-fourth inch in thickness. The sandy stratum thickens and thins, consequently there is a local irregularity of the contact line above and below but the general level around the quarry is well preserved. There are fossils but very rarely in the sandy stratum, but they are plentiful in the crystalline limestone above into which the scattering black pebbles extend for two or three inches. Very rarely the pebbles contain fossils, notably the *Chonetes yandellanus*, which is so characteristic of the cement rock.

The cement rock here is a pure homogeneous blue rock with a notable absence of those white calcareo-siliceous patches and blotches which are so apt to appear in the upper part of the ledge and injure its usefulness.

3. *The Ohio Valley Mill* was established in 1881, but has not been operated since 1898. The mill has a capacity of 800 barrels per day, with six kilns and three run of buhrs. Cement rock was last worked on leased land immediately east of the original quarry of the Silver Creek Cement Co. The rock is obtained by driving an entry 50 feet wide, a distance of 450 feet having been reached. The width of the entry makes artificial lighting and ventilation unnecessary. The motive power for the wall drills is compressed air.

A stone crusher is in operation at the quarry disposing of all the waste piles of the bastard rock stripping. The chert nodules make the rock very valuable for road metal.

A section of the quarry is as follows:

New Albany black shale	2 feet.
Bluish fine-grained bastard limestone	4 feet.
Ditto, with regular bands of chert	6 feet.
Cement rock	12 feet.

The upper member of the bastard limestone betrays a tendency to crystalline structure and in places occur numbers of *Spirifer granulosus* and stylolites with fossil cappings. Also a few large chert concretions occur. The lower member is remarkable for the evenness of the bands of cherty concretions. The two members probably represent an argillaceous phase of the Sellersburg limestone rather than the cement rock. Six inches of the cement which does not shoot loose from the roof has to be "drawn" to prevent falls.

ANALYSIS OF OHIO VALLEY CEMENT ROCK.

Calcium carbonate ($CaCO_3$)	54.31
Magnesium carbonate ($MgCO_3$)	16.90
Silica (SiO_2)	18.33
Ferric oxide (Fe_2O_3)	1.67
Alumina (Al_2O_3)	4.98
Lime (CaO)	0.14
Magnesia (MgO)	0.33
Undetermined	1.19
Total	97.85

4. *The Sable & Gilmore Mill* was one of the first to be built. It was located on the south bank of Silver Creek in the northeast corner of section 48 not far above where the railroad crosses. It ceased running about 1866 and about 1869 was torn down and moved to Watson, where it is now operated by the Queen City Cement Co. A section of the old quarry is as follows:

New Albany black shale	2 feet.
Hard crystalline fossiliferous limestone	7 feet.
Characteristic bluish cement rock	8 feet.
Cement concealed by creek	6 feet.

The lower four inches of the limestone overlying the cement rock contains the usual small rounded black pebbles.

5. *Black Diamond Mill* (Belknap & Co.)—This mill was erected in 1876 by Belknap & Co., and is just across the creek and below the preceding in the east corner of Section 86. Operations were closed in 1892 as it was found more economical to manufacture the mill's quota at the larger mill of the same company; though this mill was operated seven months in 1900 to supply an unusually heavy demand. The mill has a capacity of 700 barrels daily, operating six kilns and four run of buhrs. The cement rock was obtained by mining with compressed air as a motive power for the drills. This mill earned for its product a splendid reputation, and all of the product of the Falls City Mill and the Black Diamond River Mill in Louisville is now marketed under the Black Diamond brand. It is said that the good name of this brand resulted from the great care used in picking out the over-burned and underburned cement and because the cement was not ground so hot as was the general custom.

A section of the quarry face at the openings of the entries is as follows:

Soil	8 to 12 feet.
New Albany black shale	2 feet.
Crystalline limestone (no black pebbles)	6 feet.
Cement rock	16 feet.

The mine is at this time (Dec., 1900) partly filled with water, lying as it does, about six feet below the level of Silver Creek.

ANALYSIS OF BLACK DIAMOND CEMENT ROCK.

Calcium carbonate ($CaCO_3$)	51.95
Magnesium carbonate ($MgCO_3$)	32.97
Silica (SiO_2)	9.69
Ferric oxide (Fe_2O_3)	1.95
Alumina (Al_2O_3)	2.77
Lime (CaO)	0.10
Magnesia (MgO)	0.11
Undetermined	0.36
Total	99.90

6. *Hoosier Mill.*—The Hoosier Cement Co. erected in the fall of 1899 a plant for the manufacture of cement. It is situated just across the railroad from the preceding and has been in operation one year. It operates three Campbell patent kilns, with bases built for two more, and two sets of buhrs. Mining has been the rule from the start, and the location is well suited to that process. For those entries driven to the north and east the mine will probably be self draining or entirely dry. The section below shows that the ledge of cement rock, which is of splendid quality, is also of good thickness.

Soil	4 feet.
New Albany black shale	6 feet.
Blue-gray crystalline limestone (lower part with pebbles)	5 feet.
Cement	15 feet.

7. *The Banner Mill,* in the northeast corner of section 66, 500 yards north of the preceding; a new, complete, up-to-date plant for the manufacture of cement. The capacity of the new mill is 700 barrels daily, operating five kilns, of especial design, and two Williams & Griffin grinding mills. The cement rock is obtained by mining with the use of compressed air and electric lighting. Atten-

tion has been called in the section on *Methods of Mining* to the fact that the slope of this company is on the east side of the property and that the entries must run with the dip, with the probability of a resulting bother of drainage.

A section at the slope shows:

Soil	6 to 8 feet.
New Albany black shale	12 feet.
Gray crystalline limestone	5 feet.
Cement	16 feet.

The limestone overlying the cement seems to thicken to six to seven feet on the south and is reputed eight feet thick in the prospecting wells. It shows a small number of black pebbles at the base. A section of one of these wells in the mill yard is given as follows:

Soil	10 feet.
New Albany black shale	15 feet.
Hard gray limestone	8 feet.
Cement	16 feet.
Hard flinty limestone	56 feet.

Salt water was struck at this point and the well, which was for steaming purposes, was discontinued.

8. *The Globe Mill* was erected in 1897. It is situated in the west corner of section 67 and has a capacity of 650 barrels daily, operating 5 Campbell patent kilns and one run of buhrs. The cement rock up to the present has been obtained by open quarrying but mining has just been started. A section on the upper side of the quarry shows as follows:

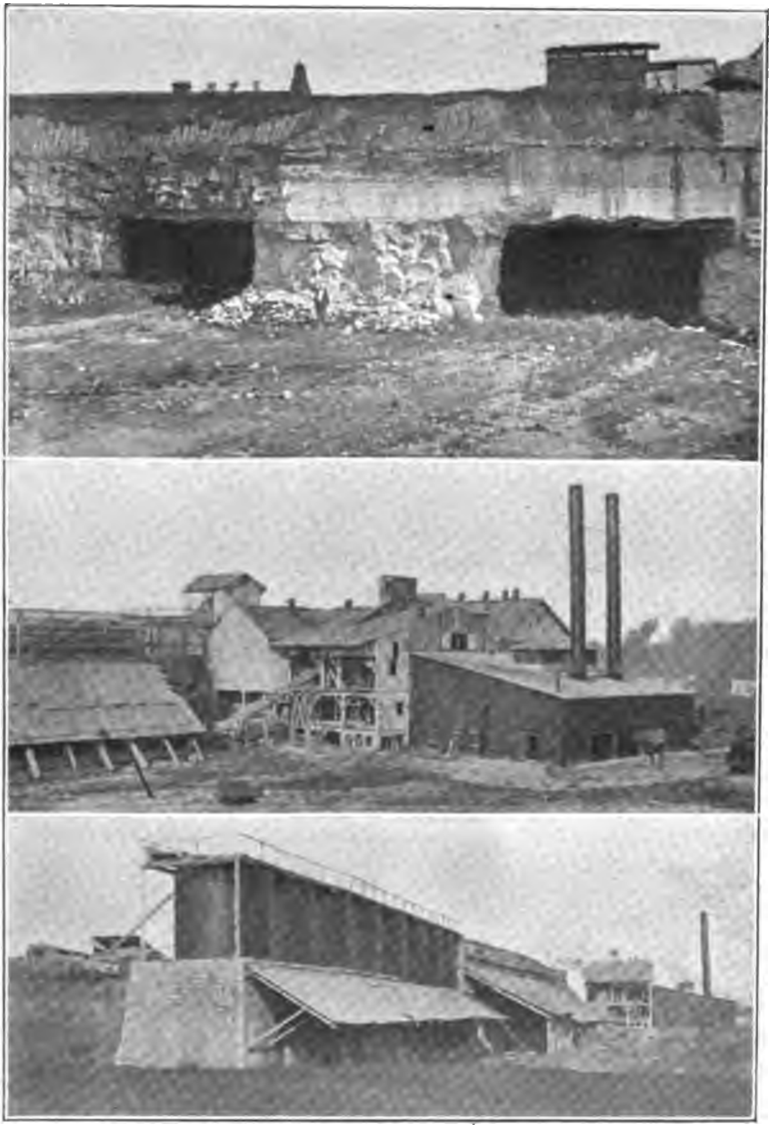
Soil	6 to 8 feet.
New Albany black shale	6 to 8 feet.
Hard gray fossiliferous limestone	5 feet.
Cement rock	16 feet.

The upper foot or so of the cement ledge has some concretionary splotches of lime and chert. A well at the mill gives this section:

Soil	10 feet.
New Albany black shale	10 feet.
Hard gray limestone	5 feet.
Cement rock	16 feet.
Hard gray limestone	40 feet.

9. *Falls City Mill* (Belknap & Co.)—This plant is situated one mile south of Sellersburg in the eastern part of section 89, and was

PLATE 14.



a

b

c

VIEWS OF FALLS CITY PLANT OF UNION CEMENT AND LIME CO.

(a) Portion of quarry, showing two tunnels.
(b) Cement mill.
(c) Kilns.

opened in 1866. In 1873 there were in operation four kilns with a daily capacity of 400 barrels. Now there are 20 kilns with a daily capacity of 2,500 barrels. At first the cement rock was obtained by open quarrying until something like 15 acres had been worked out, and then mining was resorted to. The entries are run 40 to 50 feet wide without timbering, and some of them are 600 to 800 feet long. The drills are driven by compressed air, which furnishes ventilation, though there is, in addition, an air shaft in the rear part of the mine. The mine is lighted by electricity. The rock is drawn to the mouth of the mine by mules; there a small locomotive draws it to the crusher. The company also owns a small locomotive used for switching purposes in the yards. The stripping in the south part of the quarry is quite heavy; but enough rock to make 1,500,000 barrels of cement has been stripped and the stripping crushed and sold to the county for road metal for enough to pay the expense of stripping.

A section of the quarry and quarry well is as follows:

	Ft.	In.
Soil	5	0
New Albany black shale	10	0
Bluish gray crystalline limestone	5 to 6	0
Cement rock	15	4
Hard crystalline limestone	56	0

The lower few inches of the limestone overlying the cement has the characteristic rounded black pebbles. The upper foot or so of the cement rock has scattering calcareous splotches.

ANALYSIS OF BELKNAP'S FALLS CITY CEMENT ROCK.

Calcium carbonate ($CaCO_3$)	52.50
Magnesium carbonate ($MgCO_3$)	35.09
Silica (SiO_2)	9.80
Ferric oxide (Fe_2O_3)	1.40
Alumina (Al_2O_3)	2.03
Lime (CaO)	0.04
Magnesia (MgO)	0.11
Undetermined	0.47
Total	101.44

10. *The Clark County Mill* was established in 1889. The mill is situated three-fourths of a mile south of Sellersburg in the west quarter of section 90. The daily capacity is 900 barrels, the number of kilns seven, the number of run of buhrs two. The rock is quarried in an open quarry and stripping is done by steam, as described in the

section on *Quarrying*. A section of the quarry at the upper side is as follows:

Soil	10 feet.
New Albany black shale	2 feet.
Hard light blue to gray crystalline limestone	4 feet.
Cement rock, upper ledge	4 feet.
Cement rock, lower ledge	10 feet.

The lower four to six inches of the overlying limestone is conglomeritic, most of the pebbles being in a drab, gritty bed of parting. The pebbles contain a good deal of iron, which stains the rock on exposure. The rock itself contains some flecks of pyrite here and there and decomposes readily into a black, ferruginous, residual clay, in which the characteristic fossils of formation are found in fine preservation, generally silicified.

11. *Golden Rule Mill.*—This plant was erected in 1898, about a mile northeast of Sellersburg in the west corner of section 112. It has a capacity of 500 barrels daily, operating three kilns and one run of buhrs. Open quarrying is employed at present. A section of a well at John J. Weber's, just south of the quarry, is as follows:

Soil and clay	8 feet.
New Albany black shale	9 feet.
Hard gray crystalline limestone	3 feet.
Cement rock	16 feet.

12. *United States Mill.*—This plant is situated in the north corner of the same section (112) as the preceding. It has a daily capacity of 800 barrels, operating six kilns and two run of buhrs. A section at the quarry is as follows:

Soil	4 feet.
Blue cement rock, upper ledge	3 feet.
Blue cement rock, middle ledge	2 feet.
Blue cement rock, lower ledge	8 feet.

The soil is residual from the decomposition of the limestone overlying the cement rock, and contains the pebbles found in that formation. The upper ledge of the cement rock consists of three 12-inch strata, much decomposed, and separated by arenaceous clayey partings. The middle ledge contains a great many of the lime and chert concretions. The lower ledge is the one which is used, and is the characteristic blue cement rock.

13. *Speed Mills* (J. Speed & Co.)—These mills are situated at Speed Station, and were erected in 1866. In 1873 there were in

operation eight kilns and four run of buhrs, having a daily capacity of 1,000 barrels. Now the plant consists of two independent mills, with a capacity of 4,000 barrels daily, and operating 31 kilns, 10 run of buhrs, seven coarse crushers, one Clark mill, 10 re-grinders and 18 screens.

Cement rock was long gotten from an open quarry near the mill, and something like 25 acres of ground was worked over. Recently a new quarry was opened near the middle of section 132, at a distance of one and three-fourths miles from the mills, but connected with them by a steam tramway. The new quarry is most advantageously situated for open quarrying, being located upon a flat ridge upon which the stripping will not average more than four or six feet, and that almost entirely earth. The large amount of earth stripping has led the company to develop the system of stripping by steam, as described in the section on *Quarrying*. A section of the quarry is as follows:

Soil	2 feet.
New Albany black shale	3 feet.
Black buckshot clay	1 foot.
Soft buff arenaceous rock	1 foot.
Cement rock	16 feet.

The shale exposed in this section is much decomposed and gray in color. The limestone below has decomposed entirely, giving the residual black buckshot clay, containing the characteristic fossils and black pebbles of the Sellersburg limestone. Below comes a bed of buff ocreous, arenaceous stone, apparently a weathered sandy part of the cement rock. This is cast aside in quarrying. The upper four inches of the ledge has the calcareous and siliceous blotches which have heretofore been described. The ledge itself is perfectly massive, having no vertical joint cracks and but one horizontal parting. The methods of quarrying and loading employed at this quarry have been described in the section headed *Quarrying*.

ANALYSIS OF SPEED'S CEMENT ROCK.

Calcium carbonate ($CaCO_3$)	61.70
Magnesium carbonate ($MgCO_3$)	16.74
Silica (SiO_2)	13.65
Ferric oxide (Fe_2O_3)	1.45
Alumina (Al_2O_3)	3.46
Lime (CaO)	0.15
Magnesia (MgO)	0.25
Undetermined	0.86
Total	98.56

14. *Hausdale Mill.*—This mill is situated in the northern part of section 149, two and one-half miles north of Sellersburg. It was erected in 1891 and has a daily capacity of 1,000 barrels, operating eight modern kilns and four run of buhrs. A section of the quarry shows:

	Ft.	In.
New Albany black shale	3 to 4	0
Black dirt stratum	2	6
Cement rock	16	0

The shale is gray to buff in color and much decomposed. The limestone beneath has decomposed into the residual clay stratum, the bottom part of which is very black and contains a few rounded black pebbles.

The cement rock is in three ledges. The lower one is quite blue and makes white cement, though when overburned it is like iron ore and very hard. The upper ledges are the characteristic cement rock. The rock is obtained by open quarrying, there being no roof or necessity for mining, as yet.

ANALYSIS OF HAUSDALE CEMENT ROCK.

Calcium carbonate (CaO_3)	60.69
Magnesium carbonate ($MgCO_3$)	15.90
Silica (SiO_2)	15.21
Ferric oxide (Fe_2O_3)	1.44
Alumina (Al_2O_3)	4.07
Lime (CaO)	0.07
Magnesia (MgO)	0.32
Undetermined	0.86
Total	98.56

The foregoing mills are all situated upon or connected by switches with the Louisville division of the Pennsylvania Railway. Those following are situated upon the Jeffersonville branch of the B. & O. Railway.

15. *K. & I. Mill.*—This mill is situated in the eastern corner of section 34 and was erected in 1888. It has a capacity of 900 barrels daily, operating eight kilns and two Williams grinding mills. The rock was quarried from open quarries for a time, when mining was resorted to, and entries have been driven 800 feet to the southeast, reaching nearly to the county road. Compressed air is used in two Rand wall drills and the escaping air ventilates the mine, which is

lighted by electricity. The rock is drawn from the mine to the foot of the incline by horsepower. A section of the quarry is as follows:

	Ft.	In.
Arenaceous drab limestone	2	0
Chert	0	10
Cherty "bastard" rock	9	0
Cement	10	0

The gritty drab limestone at the top of the section containing many *Spirifer granulosus* and *Atrypa reticularis* probably represents the Sellersburg limestone. The bastard rock contains a great deal of chert in the form of bands of concretions, amounting to perhaps one-half of the whole rock mass. A rock crusher, to use the chert and cherty limestone for road metal, ought to be a good investment here.

16. *Queen City Mill* (J. Speed & Co.)—This, which is the old Sable & Gilmore mill, was moved to Watson about 1869(?) It has been closed since 1893, the company finding it more economical to manufacture their quota at their large mill at Speed Station. The mill has a daily capacity of 600 barrels with six kilns and four run of buhrs. The rock was obtained by open quarrying. A section of the quarry is as follows:

	Ft.	In.
Cherty bastard rock	8	0
Shale	0	1 to 3
Cement (bottom concealed)	12	0

The ledge of bastard rock contains a great many white flint concretions with dark centers, aggregated around various fossils, as gastropods and bryozoa. The matrix contains *Spirifer granulosus*, *Atrypa reticularis* and *Chonetes yandellanus.* A thin shale parting comes between the bastard rock and the cement ledge. The cement ledge is massive and contains the same fossils as the bastard rock.

17. *Haymaker Mill.*—This mill, which is in the extreme southern corner of section 95, about two miles south of Charlestown, is a new and complete one, having been erected in 1892. It has a daily capacity of 1,000 barrels, operating eight kilns and four run of buhrs. The rock is obtained by open quarrying. A section of the quarry is as follows:

	Ft.	In.
Red soil	2	6
New Albany black shale	1	2
White crystalline encrinital limestone	4	6
Arenaceous gray limestone	0	6 to 8
Cement rock	8	0
Dark blue cement shale (bottom concealed)	2	0

The encrinital limestone just below the New Albany Black shale is exceedingly rich in crinoids, though mostly of one species, *Megistocrinus rugosus*. It also contains a number of the characteristic black pebbles distributed through a distance of six or eight inches from the bottom. The gritty stratum just below contains a great many of those pebbles which are somewhat ferruginous. It contains further a few fossils, as *Spirifer granulosus*, etc. The dark blue shale stratum at the bottom of the section is used for cement. The cement rock contains but few *Chonetes yandellanus,* but has *Spirifer mucronata*(?), *Spirifer acuminatus, Atrypa reticularis, Bryozoa* and a trilobite.

18. *Standard Mill.*—This, the most eastern of the cement works, is situated about two miles north of Charlestown, in the west corner of section 138. It was erected in 1897. The rock is obtained by mining, five entries having been driven some distance into the ledge. The mine is equipped with Rand wall drills and a compressed air plant. The mill has a capacity of 500 barrels daily, operating five kilns and two run of buhrs. A section of the quarry is as follows:

Soil	4 feet.
New Albany black shale	2 feet.
Bastard limestone	8 feet.
Cement rock	8 feet.

The bastard ledge contains no fossils, but many cherty concretions. The cement ledge also contains a good many of these.

19. *The Black Diamond River Mill* (Belknap & Co.), in Louisville, should be described as being intimately connected with the Indiana mills. Cement rock is quarried from the reef at Falls of Ohio during low water.

20. *The Hulme Mill* (J. Speed & Co.), at Shippingsport, likewise uses cement rock from the Falls of the Ohio.

For convenience of reference a tabular view is herewith presented of the different mills, their equipments and capacities.

CAPACITY AND EQUIPMENT OF CEMENT MILLS.

NAME OF MILL.	Company.	Brand.	Year Opened.	Year Closed.	Daily Capacity.	Number of Kilns.	Number of Crushers.	Number of Regrinders.	Number of Buhrs or Mills.	Number of Screens.	Number of Drills.	Method of Exploitation.
(1) Beach Mill	Wm. F. Beach	Red	1832(?)	1884	300	3	....	....	2 buhrs	....	....	Mining.
(2) Gheen's Mill	Silver Creek Cement Co	Acorn	1868	1896	800	8	....	....		....	....	Quar.Min.
(3) Ohio Valley Mill†	Ohio Valley Cement Co	Fern Leaf	1881	1898	600	6	2	....	3 buhrs	1	2	Quar.Min.
(4) Sable & Gilmore Mill	Sable & Gilmore	Diamond	?	1866								Quarry.
(5) Black Diamond Mill‡	Union Cement and Lime Co	Black Diamond	1866	....	700	6	1	1	4 buhrs	4	2	Mining.
(6) Hoosier Mill	Hoosier Cement Co	Hod and Shovel	1898	....	400	3	1	1	2 buhrs	2	2	Mining.
(7) Banner Mill‡	Banner Cement Co	Banner	1898	....	700	5	1	....	{2 Williams mills 2 Griffin mills}	3	2	Mining.
(8) Globe Mill‖	Globe Cement Co	Globe	1897	....	650	5	1	1	1 buhr	3	1	Quar.Min.
(9) Falls City Mill*‡	Union Cement and Lime Co	Anchor and Black Diamond	1866	. .	2,500	20	4	4	3 Clark mills	7	5	Quar.Min.
(10) Clark County Mill	Clark County Cement Co	Trowel and Hammer	1889	....	900	7	1	2	1 buhr	3	1	Quarry.
(11) Golden Rule Mill	Golden Rule Cement Co	Arm and Hammer	1898	....	500	3	1	2	1 buhr	3	1	Quarry.
(12) U. S. Mill	United States Cement Co	Flag	1892	....	800	6	1	2	2 buhrs	3	1	Quarry.
(13) Speed Mill*	Louisville Cement Co	Star	1866	....	4,000	32	7	12	{1 Clark mill 10 buhrs}	18	3	Quarry.
(14) Haussdale Mill	New Albany Cement Co	Crown	1891	....	1,000	8	1	2	4 buhrs	4	1	Quarry.
(15) K. and I. Mill†	Kentucky and Indiana Cement Co	Eagle	1888	....	900	8	2	....	{1 buhr 2 Williams mills}	3	3	Quar.Min.
(16) Queen City Mill†	Louisville Cement Co	Star	1869	1893	700	6	1	1	4 buhrs	3	3	Quar.Min.
(17) Haymaker Mill	Indiana Cement Co	Lion	1892	....	1,000	8	2	2	4 buhrs	4	3	Quarry.
(18) Standard Mill†	Standard Cement Co	Big Four	1897	....	500	5	1	2	2 buhrs	2	2	Quar.Min.
(19) Black Diamond River Mill	Union Cement and Lime Co	River Black Diamond	....	....	......	....	....	....		....	....	
(20) Hulme Mill	Louisville Cement Co	Star	....	....	......	....	....	....		....	....	

* Two locomotives. †Air drills. ‡ Air drills and electric lights. ‖ Steam drills.

THE INDIANA OOLITIC LIMESTONE INDUSTRY IN 1900.

By C. E. Siebenthal.

The Indiana oolitic limestone is one of the best known building stones of the United States and, in more than thirty States, has an enviable reputation as a handsome, easily-worked freestone of great durability.

Occurrence.—It occurs as a massive stratum, varying from a few feet to nearly a hundred in thickness, intercalated near the middle of the subcarboniferous limestones of Indiana. Its dendritic outcrop has been traced in detail for a distance in a direct line of nearly 110 miles through Owen, Monroe, Lawrence, Washington, Harrison and Crawford counties. Whatever be the thickness of the oolitic stratum, it is, with rare exceptions, massive, and the size of the blocks which may be quarried is limited only by the capacity of the quarry machinery and transportation facilities.

Physical Characteristics.—In texture the Indiana oolitic limestone is essentially a freestone inasmuch as it works nearly equally well in all directions. This quality is due to its massive and semi-clastic character. In places the true oolitic structure discloses its organic origin, while in other places the absence of oolite and the presence of local cross-bedding betrays its clastic origin. Occurrences of oolite are very local, by far the greater part of the stone being oolitic, but not oolite. The size of the grain varies in different parts of the area, and in different horizons at any one locality. The preference of the markets is for the finer grained, and the first grade stone is very fine grained and homogeneous. The coarser grained variety works quite as well, and when once erected can not be distinguished from the other.

The original color of the oolitic limestone varies from light to rather dark blue. On the outcrop and along the vertical clay seams, where the stone has been exposed to the leaching action of terrestrial waters impregnated with the acids of organic decomposition, the color has been changed to a buff; and the bluer the stone was

originally, the more pronounced the buff color of the altered part. The buff stone has the preference in the markets now, although a few years ago the reverse was true, and in a few years is likely to be so again. While the buff stone is necessarily restricted to that zone which has been restricted to leaching, and is limited in quantity, the blue stone, on the contrary, when once reached, extends back as far as the ledge reaches, and is practically unlimited in quantity. It is to be presumed that the blue stone, not having been subjected to leaching and weathering, is the stronger and more durable stone, though it is possible that the leaching process may result in a firmer cementation of the stone, and thus make it more durable.

RECENT DEVELOPMENTS.—In the Stinesville district the production of Bedford stone has been at a standstill for several years, but with the resumption of operations by the *Indiana Oolitic Limestone Company* and others and the opening of a new quarry by the *Stinesville and Bloomington Stone Company* things promise to resume their wonted activity in this oldest of the stone districts.

The Indiana Stone Railway is the name of a short railway line in Monroe County, finished in 1899, which has made possible the development of one of the best quarry districts in the whole oolitic field. Leaving the Chicago, Indianapolis and Louisville Railway at Clear Creek Station, it follows the tortuous valley of Clear Creek, dodging from side to side to escape the bluffs, crossing it a dozen times, and rejoins the main line at Harrodsburg Station, some nine miles from the point of departure. The quarry ledge outcrops back in the hills on each side of the main valley and of each valley branching off from it. The road will thus open up a linear extent of fifty miles of the ledge which has hitherto been inaccessible. Over this entire distance the ledge varies from forty to fifty feet in thickness and is of first quality in point of texture and color. This remarkable uniformity in thickness offers great promise that this district will in time be the greatest producer of Bedford stone in the whole belt, and already a number of quarrries have been opened.

The *Clear Creek Stone Co.* took out a large quantity of stone from its two quarries during the current season. The company will at once proceed to the erection of a large and well appointed mill.

The *Crafton Stone Co.* and the *Buff and Blue Oolitic Stone Co.* have made three openings and laid plans for the erection of a mill, but prolonged litigation has embarrassed operations very much.

The *Acme-Bedford Stone Co.* is erecting a large mill at their quarry two miles south of Clear Creek Station.

In the Bedford region the last two or three years have been marked by the abandonment of several unsuccessful quarries, and by improvements in the plants of the more successful companies, notably by the erection of the largest mill in the district by the *Bedford Quarries Co.* at Oolitic, Lawrence County.

Attention has heretofore been called to the wonderful promise of the Fishing Creek district of Lawrence County, and the prediction made that suitable development awaited it at no distant date. That prediction seems in a fair way to be verified. The *Cleveland Stone Co.* of Ohio, notwithstanding their unfortunate venture in the field in 1886, have determined to re-enter the field under the name of the American Quarries Co. This company has acquired interests in the Fishing Creek district. The Bedford Stone Railroad Company has been organized and is building from Rivervale on the Baltimore and Ohio Southwestern Railway to Leipsic on the Chicago, Indianapolis and Louisville Railway, a distance of eight miles. The road will traverse Fishing Creek valley from foot to head and open up about six miles of the ledge not now accessible.

PRODUCTION AND PRICES.—In the table appended below the price per cubic foot is the average price for the whole product including the sawed stone. Inasmuch as the amount of the sawed stone varies in its proportion to the whole amount quarried, the average is vitiated to that extent, but not enough to seriously affect it for purposes of comparison. The *Indiana Oolitic Limestone* association was formed in 1895, disbanding the same year, but not without leaving its impress on the prices for that year. The low prices which prevailed thereafter had the effect of closing down many of the smaller quarries, the number in operation running down from 95 per cent. in 1895 to 46 per cent. in 1898 and 47 per cent. in 1899. While prices have not recovered to any great extent, yet the prospects for the trade are so much better that the smaller quarries are encouraged to start up, as is shown by the 66 per cent. in operation in 1900. That the production for that year shows a slight falling off from that of 1899 is due entirely to labor troubles in Chicago which paralyzed the building trades throughout the season of 1900.

STATISTICS OF THE INDIANA OOLITIC LIMESTONE INDUSTRY FROM 1894 TO 1900, INCLUSIVE.

Year.	Cubic Feet Quarried.	Cubic Feet Sawed.	Value.	Average Price per Cubic Foot.	Total Number of Quarries.	Number of Quarries in Operation.	Percentage.	Total Number of Mills.	Number of Mills in Operation.	Percentage.
1894...........	4,580,418		$1,154,246	$0.252	35	30	86	28	24	86
1895...........	5,368,307	Statistics not collected	1,523,260	.284	38	36	95	29	26	90
1896...........	5,455,562		1,209,632	.222	39	31	79	31	27	87
1897...........	5,382,589	2,600,794	1,344,158	.250	39	26	67	31	24	77
1898...........	5,630,046	2,520,158	1,389,204	.247	39	18	46	31	23	74
1899...........	7,128,121	2,972,977	1,646,501	.231	38	18	47	32	25	78
1900...........	7,035,000	3,046,000	1,699,649	.242	38	25	66	30	25	83
Total.....	40,580,063	....	$9,966,650							

ANNUAL REPORT OF THE STATE NATURAL GAS SUPERVISOR.

LETTER OF TRANSMITTAL.

OFFICE OF STATE NATURAL GAS SUPERVISOR,
KOKOMO, IND., January 14, 1901.

Prof. W. S. Blatchley, State Geologist:

Sir—In obedience to the provisions of section 7504 of the Revised Statutes of the State of Indiana, I transmit to you herewith the ninth annual report of the State Natural Gas Supervisor. It is for the year ending December 31, 1900, and is largely confined to the work of this office during that period, and a brief statement of the present condition of the natural gas territory.

Acknowledging the cordial support that I have received from you during the past year, I remain,

Yours respectfully,
J. C. LEACH,
State Natural Gas Supervisor.

ANNUAL REPORT.

DUTIES OF THE STATE NATURAL GAS SUPERVISOR.

Briefly summarized, the duties of the State Natural Gas Supervisor, as defined by sections 7504-5 of the Revised Statutes of the State of Indiana, are as follows:

1. To make a personal inspection, as far as it is practicable, of all the natural gas wells and pipe lines in the State, the latter to be inspected as often as it may be necessary.
2. To see that all the provisions of law pertaining to the drilling of wells and the piping and consumption of natural gas are observed, and that the penalties for the violation of the same are enforced.
3. To make an annual report to the State Geologist in which shall be given certain statistical information regarding the geological formation of the gas field, the rock pressure and production of gas wells, pipe lines used for the transportaton of natural gas, manufacturing industries located on account of natural gas, and such other information as the State Geologist may require.

INSPECTION OF GAS WELLS.

The purpose of an annual inspection of gas wells in this field is to ascertain the rock pressure of the field and the rate of decrease, the production of wells and the condition of the natural gas supply in so far as these tests will reveal it. These are subjects in which all consumers of natural gas are interested and the annual reports from this office regarding the same form an interesting chapter in the history of this field. To secure this information during the early history of the field was not a difficult task. Then, the rock pressure of the entire field tended to equalize during periods of light draught, and it was but necessary to test a few wells located in different sections of the field to ascertain the field pressure. This condition has changed. In some instances a heavy draught on one section of the field does not affect localities near by. The rock pressure of the field no longer equalizes. A large number of wells located in

various sections of the field must be tested to determine the field pressure, if such it can be termed. However much interested the consumers of natural gas are in this subject at the present time, it is of minor importance when compared with that work which has for its purpose the husbanding of the supply of this gaseous fuel, and but little time has been given to it the past year.

PIPE LINE INSPECTION.

The purpose of pipe line inspection is to prevent waste. Natural gas escaping from the many pipe lines, both large and small, that line nearly every road in the gas field, attracts the attention of the public more than any other classs of waste. A very small amount of gas whistling from a pipe line near the highway will, often times, attract more attention from those unaccustomed to the work than 100,000 cubic feet of gas escaping from an oil or gas well. I do not underestimate the amount of gas that is wasted from this source; it is large, I know, and there is little excuse for it, but in its proper connection I will speak of another class of natural gas waste that is a much heavier drain upon the resources of the field than that from pipe lines and yet it receives but little attention from those most interested in the future of the gas field, the consumers. Previous to 1899 there was no law prohibiting pipe line waste and at my suggestion the General Assembly that met that year enacted a law authorizing the Natural Gas Supervisor upon the discovery of any leak in any pipe line to notify the owner or superintendent of the same to repair it and in case he does not comply within two days after receiving the said notice, it becomes the duty of the Supervisor, under the law, to make such repairs as may be necessary to stop the leak, and collect the cost of the same from the owner of the line. Though I have not had occasion to enforce the penalty provided for the violation of this law, it has rendered me very effective aid. A large majority of the waste from pipe lines comes from negligence on the part of superintendents of gas plants or field men, and one notice, as provided by law, has, to date, been sufficient. The notice provided in the act should not be necessary. An individual or corporation engaged in selling natural gas or a manufacturer owning his own gas plant should appreciate the value of this fuel enough to keep his lines in repair without notice from the State. The time has come when the law should be more drastic.

Most of the time of two men has been given to the inspection of pipe lines since last June, and, as a result, less gas is being wasted

from this source at present than at any time in the history of the field. The agitation on this subject is doing much good. There was a time when the waste of gas from any source caused but little comment. Now, the vandal-like waste of the past is rehearsed over and over by the manufacturer who finds fresh evidence of a diminishing supply of fuel each day. By some, this office is expected to stop all waste, regardless of the co-operation of the consumer and owner of pipe lines. It would be an easy task, indeed, if every one having an interest in the natural gas industry would do his duty and not permit waste from his own lines.

NATURAL GAS LAWS OF INDIANA.

The laws of the State of Indiana relating to natural gas prohibit—

1. The use of natural gas for illuminating purposes in flambeau lights. (Acts 1891, page 55.)
2. Any person, firm or corporation having possession or control of any natural gas or oil well from allowing the flow of gas or oil from such well to escape into the open air for a longer period than two (2) days next after gas or oil shall have been struck in such well. (Acts 1893, page 300.)
3. The owner or superintendent of any pipe line, machinery, apparatus, appliance or device used in the regulation and distribution of natural gas from permitting the gas in the same to escape into the open air; see "Pipe Line Inspection" above. (Acts 1899, page 83.)
4. The abandoning of oil or gas wells without properly plugging the same. (Acts 1893, page 300.)
5. The piping of natural gas from any point within this State to any point without this State. (Acts 1889, page 369.) It has been found impossible to enforce this statute, the Supreme Court upon two occasions having declared it to be unconstitutional.

By the Act of March 4, 1891 (Acts 1891, page 89) further attempt was made to regulate the production and transportation of natural gas. This act sought to accomplish four prohibitions:

1. The transportation of natural gas through pipes at a pressure exceeding 300 pounds to the square inch.
2. The transportation of natural gas through pipes by any other than natural pressure.
3. The use of any device or artificial process for the purpose of increasing the flow from the wells.
4. The use of any device or artificial process for the purpose of increasing or maintaining the flow of natural gas through pipe lines.

The attempt to enforce this statute has resulted in litigation leading to the overthrow by the Supreme Court of the State of several

features of the act on constitutional grounds. An attempt by the Manufacturers' Natural Gas and Oil Co. et al. (a number of manufacturers in the gas field, interested in the preservation of the supply of gas) to enjoin the Indiana Natural Gas and Oil Company from using artificial devices to increase the flow of gas in pipe lines has been held to be an inhibition against the right of interstate commerce and therefore unconstitutional. In the same series of cases it was further held by the Supreme Court that the attempt to discriminate between artificial and natural pressure in the transportation of natural gas was ineffectual for the same constitutional reasons. The right to prohibit the use of pumps or other devices for the purpose of accelerating the flow from the wells has been upheld as a measure of protection against the improper production of gas. Whether or not the provisions of the Act limiting the presssure to 300 pounds to the square inch in pipe lines can be enforced is not fully settled. An effort to enjoin the transportation of gas at a higher pressure, through a suit instituted by the Manufacturers' Natural Gas and Oil Co. et al., referred to above, failed in the Supreme Court on the grounds that the plaintiffs failed to show such special interest in themselves as warranted the action. The effect of this decision is, that only such persons or corporations as those whose property or persons are exposed to danger or risk incident to such extreme pressure, can be heard to complain of its use.

THE USE OF NATURAL GAS IN FLAMBEAU LIGHTS.

During the early history of the gas field and until 1896, one of the most wasteful uses of natural gas was the flambeau lights that could be seen burning night and day, year in and year out, in every section of the field. An average natural gas flambeau consumes from 150 to 200 cubic feet of gas per hour. Considering the quality of the light, this is certainly a very extravagant use, if not an absolute waste of gas. Though the law was enacted in 1891, but little was done toward enforcing it until 1896, and then much opposition was encountered. At that time, a suit instituted in the Blackford County Circuit Court to enforce it was appealed to the Supreme Court of the State, where its constitutionality was upheld. This did much to quiet the opposition that had been manifested toward it. At present, natural gas flambeaux are used by most drillers and a few manufacturers only. In many cases where they are used during winter there is a defense that would make the enforcement of the law difficult. Also, in localities where public sentiment does not favor

the enforcement of the law as written, it is difficult to secure a conviction. In this I can speak from experience. I have given all the time possible to this subject during the past year and have succeeded in getting the lights in a majority of the factories changed. In some, natural gas for illuminating purposes has given way to electricity. In others, the large lights formerly used have been replaced with more economical lights, though it is difficult to get such a light that is satisfactory for factory purposes. I do not deem it wise for me to give much time to this subject when there are so many other matters of vastly more importance that demand attention.

THE ESCAPE OF NATURAL GAS FROM WELLS.

To enforce the law relating to the escape of natural gas from wells, and thus prevent a wholesale waste of this gaseous fuel in sections of the gas field where oil is found, has consumed most of my time during the past year. What is known as the Indiana oil field is located on the northeastern border of the gas territory and embraces parts of Adams, Grant, Huntington, Jay and Wells counties. This is distinctly oil territory, and while occasionally some gas is found, the amount is insignificant compared with the value of the oil. There is not enough gas in this field for fuel purposes, pipe lines from the main gas field being necessary to supply fuel for drilling and pumping purposes.

This oil territory is contiguous to the gas field, and it is difficult to define a boundary line. Frequently wells drilled near it produce both gas and oil, and to produce the latter without wasting the gas is a difficult task, inasmuch as only a limited pressure can be held in an oil well without very materially reducing the production. If the well has been drilled to test the territory, the incentive to operate it for a short time at least is great. It is sometimes necessary to order what seems to be a productive oil well closed to prevent the waste of the gas.

DEVELOPMENT FOR OIL IN NATURAL GAS TERRITORY.

The idea is entertained by many people that "oil follows gas" and that when the gas is exhausted in this field, that the entire territory will become an oil field. This is an erroneous idea, as any person can ascertain by acquainting himself with the history of other gas fields. While undoubtedly natural gas and oil have the same origin and are stored under practically the same conditions, it does not

follow, nor is it true that the two products are always found associated. Much of the abandoned gas territory of this field does not show any signs of oil whatever, and where oil has been found it is in "sand," below the gas rock, with a hard stratum of nonporous rock between the two. The oil occupies a separate and distinct reservoir from that of the gas, though a small amount of gas is usually found with it. The gas can be produced without wasting the oil, but to produce the oil without wasting the gas is a much more difficult task. To prevent waste from this source, the law was enacted.

Though indications of oil have been present in many localities in the eastern and central part of the gas field for a number of years, no attempt was made to develop for this product in high pressure gas territory prior to 1897. A well drilled in April of that year on the Nimrod Carver farm, about two and one-half miles northeast of Alexandria, Madison County, proved to be a productive oil well, as well as a large gas well. This was the beginning of a period of waste that will never be forgotten by persons interested in the natural gas supply in that section of the field. From April 23, 1897, to March 12, 1898, seventy-five wells were drilled for oil in the vicinity of Alexandria. Of these, forty produced both gas and oil; thirty-three, gas only, and two were "dry," producing neither product. The waste of gas was enormous. To prevent damage to property the escaping gas was burned, and enough was consumed daily for weeks to supply every consumer, both domestic and manufacturing, in the city of Alexandria. At first the citizens of that city and vicinity were indifferent to this waste, and any attempt to enforce the law prohibiting it was looked upon with disfavor. The State acted promptly under the law in force at that time, which involved the infliction of a penalty only, for its violation. As most of the oil operators were nonresidents and but little was known of their responsibility, it was difficult to enforce the law, and when it was, it amounted to little more than a license, and did not stop the waste of gas. What the State wanted was to stop this, and that at once, and the penalty law failed.

March, 1898, the Supreme Court of the State decided the anti-waste law constitutional, and also that the State, or an individual interested in the supply of gas, could stop the waste of this fuel by injunction. This closed the oil wells and stopped the waste of gas in this territory for the time. These cases were affirmed by the Supreme Court of the United States, and the question was settled. In the meantime the citizens of Alexandria and the entire gas belt had awoke to the true condition, and since, the State has had their co-operation in every effort to husband the supply of this fuel.

From the time the oil wells at Alexandria were closed until the latter part of the year 1899, the oil industry in the gas field was quiet. At that time the Ohio Oil Company cleaned and started to operate five wells located on the Blake lease, about two and one-half miles northeast of Alexandria, that had been closed by injunction less than two years previous to prevent the waste of gas. On this lease it was found that the pressure of the gas had decreased until it did not seriously interfere with the production of the oil, and that the volume was not more than enough to operate the wells. This encouraged others in that locality, and at present all the wells that were closed in 1898 to prevent the waste of gas are either being operated for oil or have been abandoned. Some of the largest producers, when closed, are in the latter class. During the past year a number of wells have been drilled for oil. In cases where they produce more gas than is necessary to operate them and are not located near a large pipe line having consumers near by, sufficient to reduce the pressure in the line to a very low point, they have been closed.

Since January 1, 1900, in this locality of the gas field there have been twenty-eight old wells operated for oil. Over one-half of these are being operated at present, though the production is small. During the same period, thirty-three new wells have been drilled. Of the entire number, sixty-one, forty-five showed both gas and oil when drilled. Twelve wells produced gas only, and four did not show either product in valuable quantities. Fifteen of these wells have been closed to prevent the waste of gas, and ten are remaining closed to date. In nearly all of these wells being operated, the pressure of the gas reduces the oil production.

About three miles southeast of Marion, Grant County, is another small area of gas territory where oil is being found. In June, 1899, a "wild cat" well drilled on the B. F. Van Vactor farm, Section 15, Center Township, showed both oil and gas in large quantities. This was promptly closed by the State to prevent the waste of gas. Though all the available territory in that locality was soon under lease for oil, the closing of the Van Vactor well discouraged further drilling in that territory that year. Early in the year 1900 an old gas well located a short distance southwest of the Van Vactor well was cleaned and started to pump for oil. It showed but little gas, and a profitable oil production from the beginning. This encouraged others to drill in that vicinity. During the year 1900, fifty-five wells have been drilled for oil. Eight of these were old gas wells. Of the entire number of wells, three produce gas only, and two show neither product. The most productive wells are located in sections 15, 16, 21 and

24 of Center Township, and sections 28 and 29 of Mill Township. Twelve oil wells have been closed to prevent the waste of gas, and eight are remaining closed to date. While none of these wells are large producers, a majority are profitable, and are maintaining a fairly uniform output. The territory should not be judged by these wells, as but few show a natural production on account of the gas pressure. Though there is comparatively little gas in this field, and the companies operating it have made provision to care for any surplus that they may have, there is some difficulty in reducing the pressure in the lines to a point low enough to entirely relieve the wells.

Recently a few wells have been drilled for oil in the territory southeast of Muncie, Delaware County. Enough oil has been found to warrant further development of the territory. There is but little gas and there is no manifested disposition to waste it.

What seems to be the most productive "oil pool" that has been found in the gas belt this year is near Hartford City, Blackford County. Within the past three months twenty-three wells have been drilled, most of which are within the city limits. A few of these are very large oil wells and all produce more or less gas. Nine companies are operating in this small territory, and it has required constant work to prevent a large waste of gas, as no preparation was made to care for it at the beginning. However, large pipe lines have been laid from this territory to the factories near by, and with proper care there should be little trouble in the future. Of the twenty-three wells drilled, sixteen produce both gas and oil and seven produce gas only. Four wells have been closed to prevent the waste of gas and two are remaining closed to date.

A brief summary of the oil operations in the gas field during the past year shows that the drilling has been confined principally to four localities, to wit: Alexandria, the vicinity of Marion, Hartford City and the territory southeast of Muncie; that aside from the Hartford City "pool" no large wells have been found; that the pressure and volume of the gas, in many instances, seriously interferes with the operation of the wells, and that the natural production of the territory can not be ascertained until the gas is practically exhausted. During the year 1900, one hundred and thirty-nine wells have been drilled for oil in the gas field. This includes the old gas wells that were drilled deeper. Of these, one hundred and ten wells showed both gas and oil when drilled. Twenty produced gas only, and seven were "dry," producing neither gas nor oil. It has been necessary to close thirty-one oil wells to prevent the waste of gas, and of these, twenty are closed at present. Twenty-one wells drilled for oil have

been abandoned. It should be understood that it was not necessary for the State to institute suit to close all of these wells, but it should be equally well understood that they were closed in most cases because it is a violation of law to permit natural gas to escape into the open air from wells, and it is known that the State is compelling a strict observance of the law.

Wherever oil wells are being operated in gas territory there is more or less complaint about the waste of gas. In some cases there is just cause for this, but in many there is not. While there is always more or less waste on an oil lease where the gas pressure is high, it is not always in a manner that can be prevented by law. Many times natural gas is used so extravagantly by oil operators that its use is not less than waste, but it is not just to confine this charge to the oil field alone, for extravagance in the use of this fuel in a dwelling house or factory is just as wasteful as it is in an oil field. One of the most wasteful uses of natural gas that has come under my observation, and one that should be prohibited by law, is the use of it in steam engines instead of steam, to supply pumping power. This is one means of using the surplus gas on an oil lease. The amount of gas necessary to supply power by this means is governed by the condition of the engine, and it can not be good, after being operated with gas for a short time. Both the opportunity and incentive to use natural gas extravagantly, and even waste it where it interferes with the production of oil, is great, and in endeavoring to prevent this I have given nearly all of my time during the past year. The brief report given above suggests the results of my work. It has been my aim to enforce the provisions of the law strictly, and if I have failed in any degree I trust that the amount of work that I have tried to do will be considered.

PLUGGING OF ABANDONED GAS AND OIL WELLS.

There has been little done the past year to enforce the law regarding the plugging of abandoned gas and oil wells. This is not because the subject does not need attention, for it is a matter of vast importance to both the gas and oil industry, but because the law is defective. Attempts to enforce its provisions have proven fruitless. The present law stipulates the manner of plugging wells and provides an adequate penalty for its violation, but there is no way to ascertain when a well is to be plugged, and if so, whether according to law. Complaint is made to me that a well has been abandoned and not properly plugged. The person making the complaint was not present when

the tubing and casing were taken from the well and, in all probability, can not cite any person that was. At least it is seldom that a person can be found that can testify as to the manner that the well was plugged. The only evidence that the well is not properly plugged is the condition of the oil and gas rock in the vicinity of the well. A large number of wells have been abandoned the past year, and the annual number will increase. There is no doubt but that many of these have been left practically open, thus allowing the water to rush in and occupy the surrounding gas rock. This is very damaging to the oil and gas territory, and is a subject of much complaint from oil operators, gas companies and manufacturers. A bill will be submitted to the Legislature in session now that seeks to remedy the defects in the law in force at this time, making it possible for the State to ascertain when and how abandoned wells are plugged.

PRESSURE MAINTAINED IN PIPE LINES.

Late in October, 1900, a number of manufacturers of Muncie, Marion and Alexandria made formal complaint to this office, charging the Indiana Natural Gas and Oil Company, known as the Chicago Gas Company, with maintaining a pressure exceeding 300 pounds in its lines. The same charges were made against the Red Key Transportation Company and the Ohio and Indiana Consolidated Natural and Illuminating Gas Company. The charges against the Chicago Gas Company were especially plain and emphatic. Extravagant statements were made, some claiming that the pressure in these lines reached 1,500 pounds at times. It was not claimed by any one that these charges were based upon facts ascertained by actual tests, but upon the fact that it is *impossible* to pipe natural gas to Chicago from the Indiana field with 300 pounds pressure. The fact that former tests of the pressure in these lines had not revealed a pressure exceeding 300 pounds was given but little consideration.

The Indiana Natural Gas and Oil Company transports natural gas from this field to Chicago through two eight-inch lines and one ten-inch line. Three compressing stations are used—one near Greentown, Howard County; another near Fairmount, Grant County, and a third near Fowlerton in the same county. Each of these lines were tapped below each compressing station. Beginning November 28th, a number of tests were made, covering a period of six days, and during that time the pressure in these lines varied from 276 pounds to 295 pounds. Each test was witnessed by a number of representative citizens of the locality in which the test was made.

The fact that Chicago is a large city and could consume an enormous amount of gas accounts, in no small degree, for the current ideas in the gas field regarding the pressure in these lines. It is doubtful if the capacity of the lines or the number of wells in service has ever been considered by those making complaint. Compressing stations can not make natural gas. The Chicago Gas Company has about enough gas wells to supply, in the ordinary way, a city of 20,000 inhabitants. The product of these wells is taken to Kokomo, Indiana, and Chicago. The pipe line capacity to Chicago is four times that of any other gas company in the State having the same number of wells. It will be admitted by every one at all acquainted with the subject, that natural gas can be transported to Chicago in pipe lines at a pressure much below 300 pounds, the pressure necessary to move gas any distance being governed by the consumption. Also, it is true that the pipe line capacity of a gas plant has much to do with the amount of gas that can be carried a given distance at a given pressure. The question with a majority of manufacturers and gas companies in this field at this time is, whether to enlarge their lines or build a compressing station. I make these statements regarding the Chicago Gas Company because the complaints filed at this office made special reference to this company, and further, because there is a disposition manifested on the part of those manufacturers complaining, to discredit the tests made by this office. The tests that I have made may not furnish conclusive evidence that this company does not at times maintain an unlawful pressure in their pipe lines, but it *does* furnish conclusive evidence that natural gas can be transported to Chicago from this field for at least six days at a pressure not exceeding 300 pounds.

The Red Key Transportation Company has an eight-inch pipe line extending from the territory west of Eaton, Delaware County, to Dayton, Ohio. Three compressing stations are in use—one near Eaton, another near Red Key and a third near North Star, Ohio. This line was tested December 7th, and the highest pressure found was 210 pounds.

The Ohio and Indiana Consolidated Natural and Illuminating Gas Company has an eight-inch line extending from the north central part of Delaware County to Lima, Ohio. This line has three compressing stations—one near Eaton, another near Red Key, and a third near St. Marys, Ohio. The maximum pressure, December 7th, was 255 pounds. The pressure in the various pipe lines in the State will be tested in the future as frequently as the duties of the office will permit.

ANNUAL REPORTS.

But little time is given to the annual reports from this office. To give a full and complete report on the condition of the field would mean the neglect of much field work. These reports are published by the State and are supposed to give such information as will be most beneficial to manufacturers, gas companies and others interested in the natural gas supply. The time is here when the field work must be neglected if any time be given to reports. Those most interested in the subject ask that first consideration be given to the former and it should be, for anything that the State can do to husband this, its most valuable fuel resource, and thereby assist in more firmly establishing the many manufacturing industries that have located here to secure the advantage of using this gaseous fuel, should be done. Then, if some of the work of this office is left undone it is because all could not be done, and that which was most needed to conserve the supply of gas was given first attention. In all of my work during the past year, the one and principal object has been the husbanding of the natural gas supply of the State.

ASSISTANTS NEEDED.

It is hardly necessary for me to say, especially to those acquainted with the conditions in the gas field, that it is impossible for one man to do all the work of this office in an acceptable manner. This was probably not true when the law was enacted, 1891, but conditions have changed. At that time comparatively few wells had been drilled and but little pipe had been laid in gas territory. Most of the wells were in the vicinity of cities and towns and near the edge of the gas field. Not only has the past ten years wrought a wonderful change in the amount of natural gas property in the field, as well as in the condition of the field, but it has wrought an equal change in the work of the Natural Gas Supervisor. The increase in the number of wells and in the amount of pipe line has increased the avenues of waste, and the diminution in the supply has brought a consideration to the subject unknown in the past. Although the waste that characterized the early history of the field is no longer found, to prevent waste and the useless extravagance in the use of this valuable fuel requires a constant and vigilant watch. The entire time of one man could be given with profit to any one of the four principal gas producing counties (Blackford, Delaware, Grant and Madison) in the

gas belt. I am warranted in saying that every manufacturer and gas company in the gas belt will indorse this statement.

A number of manufacturers in Alexandria, Marion and Hartford City, and gas companies interested in the preservation of the gas supply, knowing the conditions and realizing the importance of the work, have, at their own suggestion, paid the expense of two assistants since last June. These men have worked under my directions, and the condition of the pipe lines, etc., throughout the field shows the results of their work. It should not be necessary for this expense to be paid by private individuals and corporations. Most manufacturers and gas companies are large taxpayers, and whatever benefits them benefits the entire State. Any expense necessary to carry on the work of this office should be paid by the State. I trust that the Legislature in session at this time will give this subject consideration and appropriate funds sufficient to pay the necessary expense of the office.

THE INDIANA NATURAL GAS FIELD.

It would probably be a waste of time to give any space in this report to a description of the Indiana Natural Gas Field or its history. These are subjects that have claimed considerable attention in earlier reports, and only such reference is made to them at this time as is necessary to a proper understanding of the present condition of the field; for in this, consumers of natural gas at present are more interested than in past history. It is not what the resources of the field have been, but what they are at present that interests us.

Some facts regarding this field are apparently settled in the public mind. For many years it was almost impossible to get the consumer who knew nothing about his fuel supply except what he saw at the point of consumption to face the true conditions. From actual observation he knew nothing about the decrease in the rock pressure of the wells and their volume of flow; the advance of the salt water horizon and the abandonment of wells; the necessary annual increase in the number of wells and the extension of pipe lines. To him the supply of this gaseous fuel was apparently inexhaustible. Time and changed conditions have wrought a change in the public mind. In most cases a shortage of gas has brought about an investigation of the condition of the supply, and in every case the result has been the same. When the true condition is known the necessity for husbanding the supply of this fuel resource is appreciated. On account of the mistaken ideas entertained by a majority of natural

gas consumers regarding the generation of this fuel and the stability of the supply, this gas field has suffered much. From the beginning until within the past three years, public sentiment was not only indifferent to the extravagant use and willful waste of this fuel that characterized nearly every section of this field during that period, but in many localities was positively opposed to the enforcement of laws enacted to prevent it. Strange as it may seem to those who know the conditions, it is true that in some sections of the field this spirit of indifference is still present. Where natural gas is wasted it is not often in a willful or unlawful manner, but by extravagance in its use, which, in most cases, is the result of crude appliances used in consuming it.

As I have said, the willful waste that characterized this field for so many years is fast becoming a thing of the past, though only after millions of cubic feet of this valuable fuel has been lost. Much of the waste that is found now is the result of negligence on the part of field men and those intrusted with the fuel department in factories. But it will avail but little to rehearse the mistakes of the past unless it aids us in meeting the responsibilities of the future.

DEVELOPMENT OF THE GAS FIELD, 1900.

In my last annual report I located the center of the gas field, that point toward which the principal pipe lines are being extended, a little north of the northwest corner of Delaware County. Embraced in this area were parts of Fairmount and Jefferson townships, Grant County; Washington Township, Delaware County, and Van Buren Township, Madison County. Of course there were numerous small areas of gas territory in various parts of the field, held by local gas companies and manufacturers, that had not been systematically drilled. Though this be true, these areas could not be considered as undeveloped territory, as wells drilled in it the past year show a rock pressure and production but little above those wells near by that have been in service for years. Wells drilled under these conditions are usually short lived.

Of the territory spoken of as the center of the field, about fifty square miles have not been drilled. This territory is composed of different areas, irregular in shape, and largely controlled by the principal pipe line companies. It is being rapidly and systematically drilled, and from present indications there will be but few locations left by the time this report is published.

GAS WELLS.

The condition of a gas field must be judged by the condition of the wells. More gas wells have been drilled in this field during the past year by both gas companies and manufacturers than any year previous. This does not mean that the amount of gas consumed annually is increasing, but rather that an increased number of wells is being abandoned each year and that new wells are becoming less productive. The salt water horizon in the most productive parts of the field is advancing rapidly, and in some localities has completely taken possession of the rock. Not unfrequently do seemingly productive gas wells succumb to it within six months after they are drilled. The condition of the gas rock can only be ascertained by the drill, and the result is a large increase in the number of failures. The time was when all new wells were fairly uniform in production and but few failures were recorded. Time has wrought a wonderful change in this condition, as well as others in the gas field.

The presence of the salt water in the upper strata of the gas rock can be accounted for when its structural condition and the source of the gas pressure is considered. In this field the gas rock is in the upper part of the Trenton limestone. It is here that the carbonate of lime has given way in part to carbonate of magnesia. The result is a highly crystalline limestone of sufficient porosity to contain a large amount of gas. The gas rock is not equally porous throughout, and not of a uniform thickness. It seldom comes to the surface of the limestone, from one to fifteen feet of the uppermost portion usually being hard and nonporous. As the upper surface of the gas rock is undulating, it is plain that the salt water advancing will meet the lower portions of the upper strata of hard limestone first, and thus different localities in the field will become hermetically sealed, one from the other. If the drill strikes the point in the gas rock where the salt water completely occupies it the result is evident. Also, as the volume of gas diminishes and the rock pressure gets lower, the tendency on the part of the former to move in the rock and the latter to equalize during periods of light draught becomes less. Viewed in the light of the above facts, the reason for the great difference in the volume of gas wells located in the same section of the field and their rock pressure is plain. Records of the rock pressure of this field at this time appear more like that of a number of small gas fields, wholly disconnected, than of one gas area. This condition is becoming more marked each year.

The structural condition of the gas rock, as well as the draught, has much to do with the aggressiveness of the salt water. It ap-

peared in the western part of the field and in wells that had been drilled an extra depth, and those that were subject to overdraught first. Very productive wells, with a rock pressure of 260 pounds, succumbed to this agent here before it was known to be a destructive agent in some other localities. Finally, as the draught throughout the field began to show in the diminished volume of the wells and a material decrease in the rock pressure of the field, the influence of the salt water became more pronounced, and now it is the most dangerous and difficult element with which gas companies and manufacturers have to contend. It is necessary to exercise the greatest care in drilling gas wells at this time that the gas rock may be penetrated without molesting the salt water. What can be done to counteract the influence of the salt water and thereby render the gas that is left in the rock available? If the pressure of the gas is sufficient to raise it through the tubing the task is an easy one. The water can be separated from the gas and kept out of the line. If the pressure of the gas is not strong enough to raise it through the well tubing, then the only thing to do is to reduce the well tubing to a point where the gas will lift the salt water. It is not advisable to place a small pipe within the well for the purpose of lifting the water, and permit it to remain open, as the water will be raised but the gas will be wasted. By re-tubing with small pipe and using a separator the same object will be gained without the waste of the gas. Like any other class of property, gas wells need constant attention.

PIPE LINE EXTENSIONS.

An increase in the number of wells drilled in a given year usually means an increase in the amount of pipe line laid, though for various reasons main lines are frequently extended farther into new territory than is necessary for the wells to be drilled at the time. In this manner territory is sometimes held for a time, for after a certain area has been penetrated by large lines by any one company, other companies are slow to enter it. In case they do it is usually from extreme necessity. A large amount of main line was laid in 1899, and a majority of the lines laid the past year are feeders, though in some cases they are as large as the main lines. There is a disposition at present founded upon necessity, to enlarge all gas lines. In constructing the gas plants in this field, if present conditions could have been anticipated, much labor and capital could have been saved; for, as the field pressure decreases it becomes absolutely necessary to enlarge field lines or increase the pressure by artificial means.

COMPRESSING STATIONS.

With the decrease in the rock pressure of this field came the necessity for using compressors on pipe lines. I repeat that the pressure required to transport natural gas any distance depends primarily upon the consumption. With no consumption and the pipe line perfectly tight the pressure at the outlet of the line must be the same as that at the wells, and with the line wide open at the point of consumption the loss of pressure is at a maximum. The amount of natural gas that can be transported in pipe lines a given distance depends upon the size of the line and the pressure in the same, the former governing the volume of gas and the latter its velocity. Thus as the field pressure decreases, the question presented to both gas companies and manufacturers is, whether to build compressing stations or increase their pipe line capacity. Some have adopted the former, others the latter, while occasionally it has been necessary to resort to both. The following companies have stations as indicated below in this field:

	Company	*Number of Stations.*
1.	Indianapolis Gas Company, Indianapolis	2
2.	Consumers' Gas Trust Company, Indianapolis	2
3.	Manufacturers' Natural Gas Company, Indianapolis	1
4.	Indiana Natural and Illuminating Gas Company, Lebanon, Frankfort and Crawfordsville	2
5.	Lafayette Gas Company, Lafayette	2
6.	Logansport and Wabash Valley Gas Company, Logansport, Peru, Wabash and Decatur	4
7.	Fort Wayne Gas Company, Bluffton and Fort Wayne	3
8.	Portland Natural Gas and Oil Company	1
9.	The Ohio and Indiana Consolidated Natural and Illuminating Gas Company, Lima, Ohio	2
10.	The Red Key Transportation Company, Dayton, Ohio	2
11.	Richmond Natural Gas Company, Richmond	1
12.	Indiana Natural Gas and Oil Company, Kokomo, Ind., and Chicago, Ill	3
13.	The Muncie Glass Company, Muncie	1
14.	Pittsburg Plate Glass Company, Elwood and Kokomo	1
15.	The Anderson Fuel Supply Company, Manufacturers in Anderson	1
16.	The J. M. Leach Gas Company, Manufacturers at Kokomo	1
17.	American Sheet Steel Company, Muncie	1
	Total	30

It will be noticed that manufacturers in Muncie, Elwood, Anderson and Kokomo have been compelled to build compressing stations to maintain their fuel supply. This is but a beginning. The indications are that all the larger gas companies within the gas field, whether supplying gas for domestic or manufacturing purposes, will be compelled to build compressing stations this year if they are to have satisfactory service.

ROCK PRESSURE.

As the conditions of a natural gas field must be judged by the wells, so the wells must be judged by the volume of flow, the rock pressure, etc. A diminution in the supply of gas will show in a decreased volume of flow of the wells, and in a general way, in a decrease in the rock pressure. If oil is present or salt water is invading the rock the wells will show it when open. Also, any statement regarding the condition of the wells or field, to be of value, must not only be based upon the conditions stated above, but must be comparative; that is, the conditions at present must be compared with conditions as shown by former tests.

Referring to the rock pressure of the field and its relation to the supply of gas, I quote from my last annual report: "When speaking of the condition of a natural gas field, reference is usually made to the rock or closed pressure of the wells, it being the impression of many people that, accordingly as this is high or low, so are the wells large or small. This is not true in every instance, and as the supply of gas becomes more nearly exhausted this becomes a more uncertain index of the capacity of the wells. A decrease in the rock pressure of a given area of the gas field indicates a general diminution in the supply of gas in that area, but two wells on the same farm may have the same rock pressure and be very unequal in production. The velocity of the gas at the well mouth is the only true index of the capacity of the well." The original rock pressure of the Indiana natural gas field was 325 pounds. The heavy consumption of gas by all classes of consumers, from the beginning, soon became apparent in the decline of the volume of flow and the rock pressure of wells in those localities of largest draught. This was in the zone occupied by pipe lines and in the vicinity of cities and towns, though it was not long before the decline could be noticed in all parts of the field.

At first the decline of the rock pressure throughout the field was gradual and fairly uniform, showing greatest, of course, during

periods of heavy consumption. During the summer season, when the consumption was light, the gas seemed to move freely through the rock and the pressure equalized to a certain extent. As the supply of gas has decreased the pressure has become less uniform. As has been stated, the gas rock is not uniform in thickness, both the lower and upper surfaces being more or less undulating. As the salt water raises, it may reach the upper surface of the gas rock at points and hermetically seal the gas in the more elevated portions of the same; and thus, as the field progresses, it is possible that the entire gas territory will become divided and subdivided into numerous small gas areas, varying in rock pressure, the draught on one not affecting others. To a certain extent this condition exists at this time. The draught on the wells is becoming less uniform as the rock pressure decreases. Those pipe lines connected with compressors maintain a pressure above that of the wells located below the compressing station, and as a consequence these wells are useless, a part of the time, at least. The difficulty in ascertaining the average rock pressure of the entire gas area is plain, and when found it does not give much information regarding the condition of the gas supply. The rock pressure of the territory south of an east and west line parallel with the south boundary of Hamilton County, and touching the same, is not included in the pressures given in this report. This is not because this territory does not produce gas sufficient to warrant a consideration, but because it supplies but little gas other than what is used for local domestic consumption within the territory. Regarding this part of the gas field I quote from my last annual report: "In much of this section the gas rock is thin and hard, lacking the degree of porosity found in the northern section. The gas passes slowly from the rock to the wells, and, as a consequence, they are small and seldom overworked. Pipe lines from this part of the field supply Connersville, Shelbyville and Hope. Aside from these cities the draught is largely for local domestic consumption."*

When reference is made to the Indiana Natural Gas Field, that part of the field north of the line indicated above is usually in mind. The original area of this section of the field contains approximately 2,850 square miles. As has been stated in former reports, it presents three well defined divisions. First, an outer zone surrounding the entire section. This zone varies greatly in width and has been abandoned for pipe line purposes. A part of it supplies local domestic consumption.

* Annual report of State Natural Gas Supervisor, 1899, page 208.

Second, a middle zone, which is the territory supplying pipe lines and a large majority of the factories. It varies in productiveness and has in most localities been systematically drilled. In December, 1899, this zone contained approximately 1,350 square miles. It has decreased in area very materially during the past year.

Third, the center of production, or that part of the field not invaded by pipe lines. This is a very small area located in the vicinity of the northwest corner of Delaware County. It is being very rapidly drilled. It is very difficult to ascertain the exact area of these divisions. Regarding the productive area, it is probably sufficient to say that the south two-thirds of Grant County, the south half of Blackford County, and the north half of Madison and Delaware counties supply a large per cent. of the natural gas consumed from this field.

The pressures given in this report were taken from wells located in the middle and center zones only, and are the averages of a large number of tests made in various localities. On account of the presence of the salt water it is very difficult to ascertain the exact rock pressure in many instances, but the results given here were secured under the most favorable conditions possible. This territory or zone of the gas field is decreasing annually in area and the average pressure given for each year is made from tests of the territory as it was at that time.

Tests made in this territory in November, 1897, showed an average rock pressure of 197 pounds. The same territory in 1898 showed 173 pounds rock pressure. In December, 1899, this had decreased to 155 pounds, and at present the pressure varies from 75 to 160 pounds, and the average is about 115 pounds.

CONSUMPTION AND WASTE.

Ordinarily, in referring to natural gas waste, we have in mind the escape of gas from wells, pipe lines, etc. Reference has been made to this class of waste in former sections of this report. The subject will be mentioned here only as it is involved in the consumption of this fuel. If natural gas is used extravagantly, or in heating appliances from which its full heating power is not available, it is waste, and that it is so used throughout the gas and oil field is well known. Laws have been enacted to prevent the escape of natural gas from wells, pipe lines, appliances, etc., and the enforcement of the same has reduced this class of waste to a minimum, the amount being very little compared with the same during the early history of the field. Without trying to apologize for the extravagant use of this

fuel by consumers in general, it is but fair to say that more care is being exercised in its use than formerly, though it is usually made necessary by a shortage in the supply. The fact is that but few consumers exercise that degree of economy in the use of this gaseous fuel that its value warrants or that they would were it measured to them and they were compelled to pay for what they use. The waste of natural gas that is involved in its consumption presents many difficult questions, and at present it seems that additional legislation will be required to in any measure prevent it.

THE CONSUMPTION OF GAS.

Natural gas has fulfilled its highest purpose when it has been used for the comfort and benefit of mankind. To secure this end the entire stock of gas must be consumed in such manner that the greatest possible amount of heat will be obtained and utilized. In other words, the appliances used to consume natural gas should be such as will permit a complete combustion of the gas and supply the heat to its proper purpose. Incomplete combustion not only involves waste, but fails to give the most satisfactory service. Natural gas, when used under proper conditions, is a most satisfactory fuel, a large per cent. of its heating value being attainable.

At this time when much complaint is being heard regarding the natural gas service, especially from pipe line cities, much is being said about economical appliances and methods of using gas. To those who have an opportunity to become acquainted with the usual methods of burning natural gas and utilizing its heat that are practiced throughout the gas field, this is not surprising. If the agitation had come sooner and proper methods of sale and consumption had been adopted at the beginning, the condition of the field would doubtless be different at this time.

While attending the duties of this office I have examined a large number of gas fires, both in factories and private houses, and in but few instances have I found the results of the gas consumed in the private houses to be what they should be. From incomplete combustion, which is usually the result of the use of appliances not adapted to the fuel, the domestic consumer suffers most. Not only is much of the heating power of the gas lost, but it is sure to result in the formation of carbonous oxide gas, which is extremely poisonous. To attempt to describe the various methods of using natural gas by domestic consumers would be an endless task. Generally speaking, there is not so much difference in the amount of gas used where the supply is ample as there is in the results, the latter depending entirely upon

the way it is used. In the consumption of natural gas the principal end to be attained is complete combustion, whereby all of the heating power of the gas is realized and the supplying of the heat to the room or to the purpose for which it is generated. To realize the full heating power of natural gas or to secure complete combustion it is necessary to mix it with air. The volume of air required to burn a given amount of gas is about ten times the volume of gas consumed. Too much air will tend to carry away heat through the chimney that might otherwise be utilized. In regulating a gas fire, a good method is to adjust the air supply at the mixer in such a manner that a slight white tip can be occasionally seen at the end of the flame and then turn on enough air to cause this to disappear. The supply of gas may be ample and the combustion complete, and if the heat is permitted to pass out through the chimney instead of being supplied to the room the service can not be good. Much depends, then, upon the construction of the stove or grate and the regulation of the draught. I have seen gas stoves consuming not to exceed twenty cubic feet of gas per hour giving out more heat than grates consuming two hundred cubic feet per hour. Generally speaking, a grate is very wasteful, and the best that can be said is that it makes a cheerful fire and usually insures good ventilation.

Natural gas from this field has been used for domestic purposes since 1886. During that time, comparatively little attention has been given to methods of consumption. In cases where it has, it has been caused by a shortage in the supply rather than a desire to husband it. Some reasons can be given why this condition exists and many why it should not. At the time that natural gas was discovered, wood and coal were the universal fuels. The heating apparatus in every house was arranged with especial reference to the use of one or the other, or both of these fuels. Most people began the use of natural gas with but little knowledge of how it should be used. Generally speaking, the grates, stoves, chimneys, etc., were ill adapted to the new fuel, but without any material change except a burner its use was begun. The "contract system" of selling gas was adopted by all gas companies at the beginning, and with it there is but little incentive for the consumer to exercise economy. The schedule of rates was arranged with reference to the number of fires or rooms; in some towns an annual charge was made for a residence, regardless of the amount of gas consumed. It is true, as I think, that most natural gas consumers will admit that the "contract system" of selling gas is largely responsible for the indifference manifested by the average consumer towards methods of consumption and amount of gas consumed, and but little improvement can be expected until it is forced

by a shortage in the supply or until the present system of selling is changed to one whereby the consumer is required to pay for the gas used only. Under the contract or flat rate system of selling gas the charges are the same regardless of the amount of gas used. In some cities where the supply is short at times, the consumer pays for fuel that he does not get. The system is wrong in principle and would not be considered in any other business.

There can be no question as to the just method of selling natural gas. If it is property and can be transferred as other property is, it will harm no one to pay for it as he pays for other property. Those who oppose the "meter system" contend that its adoption means a higher price for gas. This may be true, but not necessarily so. I can see no reason why the rates can not be adjusted as equitably under one system as the other. A schedule of prices under which I am compelled to pay for the gas that I use and no more is certainly just. If I choose to adopt economical appliances and practice economy, a reduction in my gas bill will follow. If I use the gas extravagantly I pay for what I use and no more. The introduction of meters at this late day would not only improve the service in many localities, but would undoubtedly prolong the life of the field. I am sure that the result would be ample recompense for the trouble and expense.

In a majority of factories natural gas is used more economically than in private residences. The reasons are plain. Most manufacturers own their fuel plant. The increasing annual expense that is necessary to maintain it has led many to investigate the subject of natural gas consumption. The result is that a majortiy have adopted improved appliances and are using less gas and having better service. The American Window Glass Company have placed meters in each of their thirty-six factories in this field. They own their fuel plants, and propose to practice the same economy in the use of their fuel as they do in the use of any other constituent of their product. The American Plate Glass Company keeps an accurate daily record of gas consumed. I do not want to be understood as saying that all manufacturers have adopted approved appliances for using gas or make an effort toward economy in the use of this fuel. A few adhere to old methods and use the gas in a manner that would indicate their belief in an inexhaustible supply. I find many cases of absolute waste that the law does not prohibit. Manufacturers, however, usually comply with any reasonable request that has for its object the husbanding of the natural gas supply. Such waste is frequently the result of negligence on the part of employes, rather than a disposition to waste the gas.

REPORT OF STATE INSPECTOR OF MINES.

OFFICE OF INSPECTOR OF MINES,
INDIANAPOLIS, IND., February 7, 1901.

Prof. W. S. Blatchley, State Geologist:

Dear Sir—I have the honor to submit to you herewith the annual report of the Inspector of Mines for the year 1900 as required by section 7454 of the Revised Statutes of Indiana, by Burns.

JAMES EPPERSON,
Inspector of Mines.

INTRODUCTION.

Inasmuch as the former reports of the Inspector of Mines cover about all the information that is desirable and of public interest, this report follows the same general lines as those which preceded it. We have, however, endeavored to make the report more complete and reliable as to the subjects included in the same than any heretofore made, and to improve on the arrangement of the matter therein.

The production of block and bituminous coal is given separately in this report, and each of these products is subdivided into machine and hand-mined coal, being a change from last year's report in this respect, which it is hoped will add to the interest and value of the report. The product is separated into screened, slack and nut, and mine run coal, and the total number of tons mined is also given. The number of kegs of powder used is omitted from the report for the reason that so much of it was purchased from persons other than operators, from whom no reports could be required, even if their names could have been ascertained, that any attempt to estimate the amount used would have been so unreliable as to be useless to any one, being a mere guess.

In giving the wages paid for day labor, the wages paid to inside and outside day men are combined, because it was impossible to get the persons furnishing this data to separate and classify them.

The table of wages in this report gives accurately the aggregate price paid for mining coal and for day labor as reported to this office. It was the purpose of this Department to give also in this report the entire cost of the production of coal and the selling price thereof. Several attempts were made during the year to collect data for this purpose, but it was found that mine operators, in most instances, were opposed to giving out this information, claiming that the same might be detrimental to their business, making it impossible to get the necessary statistics to make anything like an accurate statement.

The geological number of the coal seams of each mine is given in the general table, and a table has been added of mines in which mining machines or mechanical haulage is being used.

This report includes the following matter, arranged in the order enumerated: Letter of transmittal, introduction, miscellaneous table, coal trade and mining conditions, miners' and operators' wage agreement, labor troubles, tonnage and wage tables, new mines, abandoned mines, table of machine mines, improvement of mines, examinations, certificates of competency, certificates of service, table of small mines, mine bosses and addresses, companies and addresses, table of accidents, changes in the mine management, and opinions of Attorney-General.

TABLE

Showing Name of Mine, Depths and Thickness of Coal, Geological Number of Coal Seams, Number of Persons Employed Inside, Number of Persons Employed Outside, Total Number of Employees, Days Worked, Number of Mules Used, Accidents, Tons of Screened, Slack and Nut and Mine Run Coal Produced, Total Tons of Coal Produced, Wages Paid to Miners, Wages Paid to all Other Labor, Total Wages Paid Exclusive of Office Employees, Tons of Block Coal Mined by Machines, Tons of Block Coal Mined by Hand, Tons of Bituminous Coal Mined by Machines, and Tons of Bituminous Coal Mined by Hand.

BLOCK COAL MACHINE MINES.

CLAY COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Brazil Block No. 1	100	3-8	IV	101	18	119	18	8	5	48,694	8,604	64	57,362	$44,177 79	$34,210 01	$78,387 80
Brazil Block No. 8	89	3-8	III	147	15	162	260	11	2	76,831	14,760	....	91,591	65,193 93	38,656 96	103,850 88
Brazil Block No. 11	74	{4-0 {3-6	IV III	} 85	9	94	163	16	1	42,098	7,955	109	50,162	36,464 43	17.241 15	53,705 58
Gart No. 10	65	3-6	III	69	6	66	128	6	2	23,200	4,267	....	27,467	19,666 04	14,232 59	33,898 63
Diamond No. 3	103	3-6	III	58	8	66	208	6	....	29,714	4,295	....	34,009	21,454 32	15,996 88	37,451 20
Diamond No. 5	96	3-6	IV	43	8	51	171	3	....	14,846	2,445	....	17,291	12,389 00	10,087 60	22,476 60
Briar Hill	116	3-6	IV	42	8	50	160	7	....	13,303	2,123	4,587	20,013	12,187 41	7,791 97	19,179 38
Totals	....	......	......	536	72	608	.....	58	10	248,686	44,449	4,760	297,895	$211,532 92	$138,217 15	$349,750 07

BLOCK COAL MACHINE MINES—Continued.

PARKE COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Brazil Block No. 12	150	3-6	IV III	98	11	109	232	12	12	35,827	7,145	8,136	51,108	$35,960 88	$23,609 97	$59,570 85
Totals	....	......	......	98	11	109	232	12	12	35,827	7,145	8,136	51,108	$35,960 88	$23,609 97	$59,570 85
Totals in Block Coal Machine Mines	....	......	......	634	83	717	.....	70	22	284,513	51,594	12,896	349,003	$247,493 80	$161,827 12	$409,320 92

BITUMINOUS MACHINE MINES.

DAVIESS COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Cable No. 9	85	4-6	V	167	9	176	265	14	2	5,408	2,557	85,994	93,959	$37,822 92	$31,547 27	$69,370 19
Totals	....	......	......	167	9	176	265	14	2	5,408	2,557	85,994	93,959	$37,822 92	$31,547 27	$69,370 19

GREENE COUNTY

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Island No. 1	66	5-0	IV	80	11	91	148	10	2	7,107	15,793	52,697	75,597	$29,713 73	$20,232 07	$49,945 80
Island No. 2	95	5-0	IV	134	17	151	157	21	3	46,352	40,863	34,254	121,469	54,193 12	33,756 26	87,949 38
Summit No. 2	150	5-6	IV	90	11	101	88	10	10	32,748	11,121	1,900	45,769	15,599 87	13,480 14	29,080 01
Hoosier	133	3-7	IV	20	6	26	36	1	....	....	....	1,789	1,789	536 10	1,794 00	2,330 10
Black Creek	....	4-8	IV	19	7	26	20	2	1	1,587	1,099	62	2,748	1,170 37	1,941 12	3,111 49
Totals	....	......	......	343	52	395	.....	44	16	87,794	68,876	90,702	247,372	$101,213 19	$71,203 59	$172,416 78

PARKE COUNTY.

Parke No. 8	125	6-0	VI	90	11	101	219	10	1	15,134	9,164	58,647	82,945	$36,870 56	$20,327 02	$57,197 58
Cox No. 3	185	6-0	VI	94	24	114	163	15	2	39,015	16,966	19,156	75,137	35,063 24	34,349 08	69,412 32
Totals	....	......	......	184	35	215	.....	25	3	54,149	26,130	77,803	158,082	$71,933 80	$54,676 10	$126,609 90

PIKE COUNTY.

Hartwell	....	4-0	V	20	3	23	170	2	4	....	....	16,996	16,996	$4,119 37	$5,708 73	$9,828 10
Totals	....	4-0	V	20	3	23	170	2	4	....	....	16,996	16,996	$4,119 37	$5,708 73	$9,828 10

SULLIVAN COUNTY.

Phœnix No. 1	37	7-0	V	166	25	191	176	18	4	....	....	182,003	182,003	$61,830 02	$44,827 90	$106,657 92
Phœnix No. 3	*	7-0	V	......	......	......	....	2	2	....	Report	ed with	Phœnix	No. 1.		
Phœnix No. 5	*	7-0	V	......	......	......	....	1	....	....	Report	ed with	Phœnix	No. 1.		
Star City	120	5-0	VI	121	21	142	197	27	3	98,379	47,573	7,770	153,722	51,149 52	44,669 86	95,819 38
Shelburn	240	5-6	VI	55	11	67	146	8	2	16,149	11,470	1,245	28,864	14,232 55	13,476 10	27,708 65
Bunker Hill	72	4-6	VI	41	8	49	189	6	1	11,833	6,082	5,544	23,459	4,693 65	6,578 24	11,271 89
Dugger	105	5-0	VI	100	17	117	196	12	4	52,955	24,172	31,615	108,742	40,981 97	26,168 86	67,150 83
Jackson Hill No. 1	24	5-8	VI	120	13	133	182	27	4	45,777	70,332	36,308	152,417	49,227 18	31,598 33	80,825 51
Jackson Hill No. 2	104	5-8	VI	50	9	59	200	7	....	32,644	38,990	19,116	90,750	27,788 75	13,346 24	41,134 99
G. Ingle	50	4-8	VI	50	7	57	4	....	....	13,654	6,266	12,050	31,970	12,804 29	8,301 90	21,106 19
Hymera	127	6-0	V	65	17	82	208	9	1	20,372	16,556	20,440	57,368	20,739 79	12,564 36	33,304 15
Totals	....	......	......	768	128	896	.....	115	21	291,763	221,441	134,088	647,292	$283,447 72	$201,531 79	$484,979 51

VIGO COUNTY.

Parke No. 10	100	6-6	VI	125	14	139	225	11	....	44,425	38,550	68,987	151,962	$61,122 83	$29,140 44	$90,263 27
Glen Oak (no report)	50	6-6	VI	......	......	......	....	....	1	....	....	....	....	....	....	....
Ray	110	7-0	VI	136	11	147	161	11	....	42,320	24,236	44,776	111,332	47,593 13	24,119 02	71,712 15
Totals	....	......	......	261	25	287	306	22	1	86,745	62,786	113,763	263,294	$108,715 96	$53,259 46	$161,975 42

BITUMINOUS MACHINE MINES—Continued.

VANDERBURGH COUNTY

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Sunnyside	235	4-0	V	72	10	82	205	11	3	23,639	10,544	17,486	51,669	$26,110 60	$19,555 90	$45,666 50
Totals	235	4-0	V	72	10	82	205	11	3	23,639	10,544	17,486	51,669	$26,110 60	$19,555 90	$45,666 50

WARRICK COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Big Vein	*	7-0	VI	37	5	42	189	6	1	....	....	48,319	48,319	$16,467 90	$7,539 20	$24,007 10
Totals	....	......	......	37	5	42	189	6	1	....	....	48,319	48,319	$16,467 90	$7,539 20	$24,007 10
Totals in Bituminous Machine Mines	.....	.....	......	1,852	267	2,119	.....	272	50	549,498	392,334	585,151	1,526,983	$649,831 46	$445,022 04	$1,094,853 50

BLOCK COAL—HAND OR PICK MINES.

CLAY COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Gart No. 3	120	4-0 3-4	IV III	80	8	88	210	9	1	29,192	6,655	2,123	37,970	$28,262 22	$15,616 22	$43,878 44
Gart No. 5	77	4-0 3 6	IV III	139	10	149	153	10	....	52,389	10,085	7,872	70,346	53,620 14	20,666 29	74,286 43
Gart No. 7	*	4-0	IV	20	....	....	.....	2	1	....	....	5,039	5,039	3,901 36	151 42	4,052 78
Louise	106	3-4	III	33	3	36	119	3	1	7,825	1,582	220	9,627	6,860 96	2,859 29	9,720 25
Monarch	81	3-6	IV	18	2	20	292	2	....	....	....	8,675	8,675	9,716 89	2,653 60	12,370 49
Gladstone	125	4-6	IV	72	8	80	206	10	....	....	....	45,085	45,085	34,880 26	18,267 75	53,148 01

Pratt	129	3-4	IV	65	6	71	208	8	2	23,630	2,415	5,536	31,581	23,332 00	11,182 00	34,514 00
Eureka No. 2	99	{4-0 3-6	IV III}	68	5	73	174	8	1	29,277	6,418	....	35,695	28,840 75	10,148 40	38,989 15
Eureka No. 3	40	3-3	III	69	6	75	202	6	2	24,221	7,200	1,611	33,032	30,115 90	8,640 65	38,756 55
Eureka No. 4	80	{4-0 3-6	IV III}	46	3	49	50	3	1	6,446	1,685	....	8,131	7,944 05	1,653 05	9,597 10
Rob Roy	97	{4-0 3-4	IV III}	30	5	35	205	3	2	10,893	1,348	474	12,715	10,284 62	6,420 52	16,705 14
Dewey	64	3-6	III	61	3	64	163	4	....	22,522	4,721	....	27,243	21,127 09	8,240 39	29,367 48
Crawford No. 2	75	3-6	III	18	4	22	64	2	1	2,124	560	....	2,684	4,112 89	2,897 69	7,010 58
Crawford No. 3	90	3-4	III	63	5	68	131	3	....	24,481	4,714	....	29,195	22,826 17	8,784 89	31,611 06
Crawford No. 4	86	6-4	III	48	6	54	123	4	6	14,944	3,068	....	18,012	13,705 35	6,700 04	20,405 39
Crawford No. 5	.....	3-8	III	90	6	96	169	4	1	25,439	5,630	6,584	37,653	28,390 62	5,949 94	34 340 56
Columbia No. 4	120	4-0	III	60	5	65	134	4	2	18,884	5,000	26	23,910	20,166 37	6,003 89	26 170 26
Columbia No. 5	85	4-0	III	106	7	113	177	7	....	392,724	14,591	550	406,864	35,413 38	10,588 81	46,002 19
Markland	85	3-6	III	23	5	28	142	3	....	7,291	2,381	....	9,072	5,982 00	2,894 30	8,876 30
Harrison No. 2	75	3-6	IV	36	5	41	168	3	....	11,791	3,020	740	15,551	11,803 50	4,811 20	16,614 70
Harrison No. 3	82	3-6	IV	31	3	34	163	3	....	9,225	2,690	129	12,044	8,893 05	3,028 35	11,921 40
Cornwall	86	{4-0 3-6	IV III}	40	4	44	182	2	....	8,301	2,486	....	10,787	8,500 41	7,095 58	15,595 99
Totals	....	......	......	1,216	111	1,327	.....	103	21	721,599	86,248	84,664	892,511	$418,679 98	$165,254 27	$583,934 25

PARKE COUNTY.

Otter Creek	33	{4-0 3-8	IV III}	42	3	45	168	3	2	18,658	3,246	2,872	24,776	$17,483 99	$8,263 80	$25,747 79
Standard	100	{4-6 3-4	IV III}	79	5	84	192	7	1	38,400	10,735	3,567	52,702	35,617 00	10,848 00	46,465 00
Superior No. 1	108	{4-0 5-0	IV III}	80	6	86	136	7	2	42,681	10,485	661	53,827	40,576 98	17,884 71	58,461 69
Mary	105	4-10	III	28	4	32	198	3	....	7,860	1,180	....	9,040	9,499 48	3,758 74	13,258 22
McIntosh No. 3	90	3-4	III	90	5	95	169	4	2	33,689	8,415	554	42,658	30,989 00	15,074 00	46,063 00
Crawford No. 1	35	3-6	III	47	4	51	178	2	1	20,166	3,924	65	24,155	16,909 83	6,618 36	23,528 19
Superior No. 2	135	{4-0 3-6	IV III}	125	7	132	184	9	2	49,063	11,835	2,528	63,426	50,487 69	16,687 68	67,175 37
Totals	....	......	......	491	34	525	.....	35	10	210,517	49,820	10,247	270,584	$201,563 97	$79,135 29	$280,699 26
Totals in Block Coal, Hand or Pick Mines	....	......	......	1,707	145	1,852	.....	138	31	932,116	136,068	94,911	1,163,095	$620,243 95	$244,389 56	$864,633 51

BITUMINOUS HAND OR PICK MINES.

CLAY COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Gifford	110	4-4	III	76	6	82	90	4	....	5,299	1,298	702	7,299	$5,639 10	$5,275 14	$10,914 24
Klondyke	25	7-0	VI	151	11	162	149	10	5	55,425	36,726	19,454	111,605	50,811 65	14,524 87	65,336 52
Silverwood No. 3	62	6-6	VI	58	7	65	230	4	....	29,148	15,516	....	44,664	23,065 15	10,528 07	33,593 22
San Pedro	48	7-0	VI	26	7	33	95	5	1	6,711	4,145	1,114	11,970	5,910 58	4,092 14	10,002 72
Cloverland	100	7 0	VI	136	10	146	150	6	1	41,332	17,331	25,194	83,857	49,665 24	12,742 13	62,407 37
Fortner	100	3-4	V	29	4	33	82	9	1	4,435	1,898	729	7,062	6,120 48	2,969 92	9,090 40
Pearl	32	7-0	VI	65	6	71	168	6	....	24,630	12,034	4,150	40,814	21,841 36	7,388 02	29,229 38
Totals	....	......	......	541	51	592	.....	44	8	16[illegible],980	88,948	51,343	307,271	$163,053 56	$57,520 29	$220,573 85

DAVIESS COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Cable No. 4	42	2-10	V	57	5	62	200	5	....	11,196	3,778	,650	16,624	$12,083 90	$6,253 62	$18,337 52
Hoosier	50	3- 7	III	Working fewer than ten men.												
Wilson No. 4	*	3- 6	V	16	3	19	74	....	....	3,848	626	....	4,474	4,400 04	1,475 75	5,875 79
Montgomery No. 2	65	3- 8	IV	61	8	69	169	5	3	....	....	41,454	41,454	25 571 30	12,069 00	37,640 30
Montgomery No. 3	100	3- 8	IV	93	9	102	219	7	2	2,600	1,400	53,376	57,376	31,711 55	13,743 70	45,455 25
Union	50	3- 0	III	17	2	19	113	....	....	....	....	5,437	5,437	2,285 61	503 43	2,789 04
Hawkins	64	6- 0	V	20	4	24	189	2	....	....	....	8,606	8,606	5,355 82	3,735 73	9,091 55
Mutual	100	4- 6	III	41	6	47	213	4	....	13,140	1,125	3,540	17,805	12,065 00	5,924 40	17,989 40
Black Diamond	82	3- 4	III	12	2	14	24	2	....	5,130	2,070	1,095	8,295	530 00	261 10	791 10
Totals	....	......	......	317	39	356	.....	25	5	35,914	8,999	115,158	160,071	$94,003 22	$43,966 73	$137,969 95

FOUNTAIN COUNTY.

Sturm	55	4-8	V	12	3	15	77	3	....	680	185	2,244	3,109	$1,495 00	$1,186 00	$2,681 00
Silverwood	86	4-6	V	50	7	57	239	4	3	25,751	12,060	720	38,531	22,614 51	12,092 19	34,706 70
Totals	....	......	......	62	10	72	.....	7	3	26,431	12,245	2,964	41,640	$24,109 51	$13,278 19	$37,387 70

GREENE COUNTY.

Island Valley No. 1	52	5-0	IV	60	6	66	198	6	4	16,375	9,392	26,111	51,878	$5,450 79	$11,440 35	$36,891 14
Island Valley No. 2	37	5-4	VI	35	6	41	59	3	3	12,635	1,653	52	14,340	4,104 28	1,989 08	6,093 36
Island Valley No. 3	47	5-6	IV	52	8	60	133	7	4	10,111	5,170	15,147	30,428	17,981 75	6,690 39	24,672 14
Fluhart	72	5-0	IV	106	11	117	144	12	3	17,932	4,986	31,792	54,710	31,505 47	14,800 96	46,306 43
South Linton	81	5-0	IV	101	9	110	162	9	5	33,038	16,958	39,688	89,684	48,063 99	12,267 99	60,331 98
Summit No. 1	95	5-0	IV	48	7	55	103	7	2	65,903	29,227	19,908	115,038	41,296 48	26,436 15	67,732 58
Templeton	52	5-0	IV	150	10	160	.....	12	4	13,866	8,454	93,442	115,762	59,195 00	16,637 60	75,832 60
Wild Cat	102	4-6	IV	80	11	91	110	6	2	5,889	5,220	16,162	27,271	18,8[illegible]4 27	7,964 92	26,839 19
Totals	....	......	......	632	68	700	.....	62	27	175,749	81,060	242,302	499,111	$246,471 98	$98,227 44	$344,699 42

GIBSON COUNTY.

Oswald	450	6-10	V?	76	15	91	162	10	5	23,450	13,811	22,159	59,420	$28,759 53	$14,903 97	$43,663 50
Totals	....	......	......	76	15	91	162	10	5	23,450	13,811	22,159	59,420	$28,759 53	$14,903 97	$43,663 50

KNOX COUNTY.

Knox	103	4-4	VI	32	3	35	25	2	....	562	322	84	968	$941 52	$2,095 92	$3,037 44
Bicknell	92	4-4	VI	37	5	42	175	3	1	7,093	4,646	12,659	24,398	11,043 75	4,714 50	15,758 25
Edwardsport	45	4-6	VI	46	6	52	226	6	3	9,239	6,134	9,000	24,373	16,728 46	11,351 35	28,079 81
Prospect Hill	335	3-0	VII	14	4	18	188	3	....	4,244	2,301	3,[illegible]98	9,643	5,542 55	4,176 66	9,719 21
Totals	....	......	......	129	18	147	.....	14	4	21,138	13,403	24,841	59,382	$34,256 28	$22,338 43	$56,594 71

BITUMINOUS HAND OR PICK MINES—Continued.

MARTIN COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labo.	Total Wages Paid.
Tunnel	†	2-8	III	20	2	22	267	2	....	1,129	794	6,343	8,266	$4,842 00	$1,981 41	$6,823 41
Totals	....	......	......	20	2	22	267	2	....	1,129	794	6,343	8,266	$4,842 00	$1,981 41	$6,823 41

PIKE COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labo.	Total Wages Paid.
Rogers	†	7-0	V	12	2	14	41	1	....	....	....	3,263	3,263	$681 06	$667 83	$1,348 89
Littles	80	6-6	V	77	10	87	129	11	3	10,161	11,997	28,413	50,571	23,804 97	9,597 51	33,402 48
Blackburn	*	6-6	V	49	8	57	115	7	....	11,582	12,468	7,421	31,471	14,564 18	2,936 35	17,500 53
Wooley	52	5-0	V	55	7	62	86	5	....	....	....	21,012	21,012	9,729 25	11,379 90	21,109 15
Carbon	*	4-6	V	20	5	25	104	4	2	81	80	8,232	8,393	4,525 82	2,803 16	7,328 98
Ayrshire No. 3	22	5-0	V	179	20	199	209	16	6	29,974	19,541	48,919	98,434	47,708 91	32,743 64	80,452 55
Ayrshire No. 4	†	4-8	V	.....	.....	.....	.....	2	....	Reported	with	Ayrshire	No. 3.			
Ayrshire No. 5	*	5-0	V	25	3	28	110	4	....	421	341	11,281	12,043	7,060 07	2,286 99	9,347 06
Alden	†	5-6	V	10	2	12	15	2	....	1,364	1,377	1,324	4,065	3,248 00	1,480 00	4,728 00
Aberdeen	43	4-6	V	33	4	37	32	2	....	71	71	3,414	3,556	3,072 00	396 00	3,468 00
Totals	....	......	......	460	61	521	.....	54	11	53,654	45,875	133,279	232,808	$114,394 26	$64,291 38	$178,685 64

PARKE COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labo.	Total Wages Paid.
Mecca No 1	130	{ 3-4 4-10	IV III	} 52	8	60	219	7	3	11,372	6,065	24,396	41,833	$23,457 47	$15,167 79	$38,625 26
Lucia	134	4-0	III	63	7	70	185	7	3	24,407	12,772	15,525	52,704	28,655 00	15,478 00	44,133 00
Lyford No. 2	185	6-6	VI	134	14	148	143	14	6	9,168	4,847	90,698	104,713	54,259 61	32,537 34	86,796 95
Totals	....	......	......	249	29	278	.....	28	12	44,947	23,684	130,619	199,250	$106,372 08	$63,183 13	$169,555 21

PERRY COUNTY.

Cannelton	†	2-8	II	24	5	29	90	3	3	907	....	16,844	17,751	$8,469 48	$6,527 40	$14,996 88
Sulphur Springs	*	2-8	......	......	......	......	......	1	....	499	....	600	1,099	656 12	190 11	846 23
Troy	50	3-0	II	12	2	14	187	1	....	....	....	4,630	4,630	3,345 92	51,900 02	55,245 94
Totals	....	.....	......	36	7	43	.....	5	3	1,406	....	22,074	23,480	$12,471 52	$58,617 53	$71,069 05

SULLIVAN COUNTY.

Caledonia	106	5-3	VI	71	6	77	241	5	7	30,792	10,250	16,731	57,773	$24,151 41	$19,381 09	$43,482 50
Briar Hill	100	5-0	VI	80	4	84	149	4	....	7,309	2,746	4,178	14,233	8,718 92	4,409 21	13,128 13
Sullivan (idle)	185	3-6	VII	......	......	......	......	....	....	....	....	....	....	....	....	....
White Ash	53	6-0	V	35	4	39	183	4	....	7,280	4,800	9,305	21,385	12,727 67	4,151 63	16,879 30
Green Hill	120	4-6	VI	20	5	25	93	2	....	3,746	2,517	1,732	7,995	3,400 00	3,135 00	6,535 00
Sunflower (new mine, no report)	....	......	VI	......	......	......	......	....	....	....	....	....	....	....	....	....
Totals	....	.....	......	156	19	175	.....	15	7	49,127	20,313	31,946	101,386	$48,998 00	$31,026 93	$80,024 93

VIGO COUNTY.

Peerless	101	7-0	VI	110	9	119	170	14	12	45,702	20,520	8,998	75,220	$42,974 00	$17,988 00	$60,962 00
Diamond	54	6-0	VI	160	10	170	255	17	1	68,798	30,370	31,651	130,819	77,362 00	28,644 00	106,006 00
Grant No. 1	80	6-6	VI	52	6	58	187	6	2	18,091	10,325	22,758	51,174	24,365 03	12,334 18	36,699 21
Nickleplate	10	7-0	VI	58	7	65	160	5	1	....	....	47,739	47,739	10,674 60	17,559 35	28,233 95
Klondike	*	6-6	VI	70	9	79	161	4	1	17,920	11,273	21,927	51,120	26,545 67	10,380 75	36,926 42
Ehrlich	99	7-0	VI	56	7	63	184	7	....	27,368	19,925	....	47,293	22,704 19	9,194 12	31,898 31
Koch	*	6-6	VI	25	6	31	42	2	....	....	....	1,407	1,407	899 98	468 60	1,368 58
Hecktor	133	7-0	VI	66	7	73	188	5	2	20,081	14,309	6,590	40,980	19,413 98	10,680 55	30,094 53
Red Bird	90	6-0	VI	18	2	20	76	1	4	723	383	673	1,779	909 45	674 72	1,584 17
Brick Works	35	4-4	VII	9	2	11	111	2	....	....	....	4,066	4,066	1,916 72	1,034 83	2,951 55
Miller Bros	85	4 4	VII	Working fewer than ten men.												
Murry	27	4-4	VII	Working fewer than ten men.												
Broadhurst	89	4-4	VII	14	2	16	180	2	1	3,982	2,963	3,852	10,797	5,654 13	2,472 21	8,126 34
Larimer (no report)	110	4 8	VII	Working fewer than ten men.												
Vigo	*	6-6	VI	25	3	28	7	3	....	....	....	575	575	250 00	175 00	425 00
Grant No. 2	120	6-6	VI	61	7	68	208	2	....	2,910	7,570	39,878	50,358	29,170 17	10,288 10	39,458 27
Pfaelzer	*	6-0	VI	56	5	61	120	4	1	2,795	1,245	22,515	26,555	15,453 37	5,099 99	20,553 36
Lawton (new mine, no report)	110	6-6	VI	......	......	......	......	....	....	....	....	....	....	....	....	....
Royal	103	6-0	VI	36	5	41	53	1	....	4,092	2,254	362	6,708	4,054 90	1,761 31	5,816 21
Glen (new mine, no report)	101	4-6	III	......	......	......	......	....	....	....	....	....	....	....	....	....
Totals	....	.....	......	816	87	903	.....	75	25	212,462	121,137	212,991	546,590	$282,348 19	$128,755 71	$411,103 90

BITUMINOUS HAND OR PICK MINES—Continued.

VANDERBURGH COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Union	235	4-0	V	33	6	39	183	3	....	6,997	3,506	6,997	17,500	$13,220 00	$5,015 75	$18,235 75
Unity	225	4-0	V	14	4	18	.....	1	....	....	....	4,189	4,189	1,984 50	1,234 50	3,210 00
Ingleside	235	4-0	V	57	7	64	224	5	2	....	....	48,906	48,906	23,372 39	16,041 31	39,413 70
First Avenue	265	4-0	V	35	8	43	221	6	2	9,857	6,108	18,215	34,180	22,013 75	9,135 30	31,149 05
Diamond	256	4-0	V	22	5	27	253	4	....	7,920	4,484	3,714	16,118	9,727 51	7,835 37	17,562 88
Totals	....	......	......	161	30	191	.....	19	4	24,774	14,098	82,021	120,893	$70,318 15	$39,262 23	$109,580 38

VERMILLION COUNTY.

NAME OF MINE.	Depths to Coal in Feet.	Thickness of Coal Seam in Feet and Inches.	Geological No. of Coal Seams.	Number of Persons Employed Inside.	Number of Persons Employed Outside.	Total Number of Persons Employed.	Days Worked.	Number of Mules Used.	Accidents.	Tons of Screened Coal.	Tons of Slack and Nut Coal.	Tons of Mine Run Coal.	Total Tons of all Kinds of Coal Produced.	Wages Paid to Miners.	Wages Paid to all Other Labor.	Total Wages Paid.
Buckeye	165	6-0	VI	90	8	98	193	11	9	42,897	34,196	14,136	91,229	$52,998 79	$22,642 21	$75,641 00
Brouillet's Creek No. 3	265	6-0	VI	97	8	105	108	8	4	29,606	44,850	63,660	138,116	64,250 66	15,049 45	79,300 11
Brouillet's Creek No. 4	45	4-10	VII	130	9	139	200	11	4	26,065	18,000	140,867	184,932	85,994 85	17,616 55	103,611 40
Brouillet's No. 5	85	4-10	VII	125	6	131	158	2	....	12,415	2,065	36,180	50,660	25,517 59	8,091 19	33,608 78
Prince	130	4-10	VII	139	12	151	222	15	4	25,398	20,715	83,355	129,468	76,195 12	33,683 06	109,878 18
Torrey No. 4	285	6-0	VI	97	10	107	225	12	14	....	....	91,208	91,208	50,384 90	24,674 20	75,059 10
Eureka (see Note 2)	110	5-0	VIa VI	9	2	11	270	2	4	....	....	15,148	15,148	5,022 12	2,924 88	7,947 00
Oak Hill	40	4-10	VII	125	6	131	158	8	....	12,415	2,065	36,108	50,588	25,517 59	8,091 19	33,608 78
Willow Grove (new mine, no rep't)	176	6-0	VI	Work	ing f	ewer	than	ten	me	n.						
Totals	....	......	......	812	61	873	.....	69	39	148,796	121,891	480,662	751,349	$385,881 62	$132,772 73	$518,654 35

WARRICK COUNTY.

Star No. 1	100	4-4	V	46	7	53	159	6	2	....	....	36,534	36,534	$16,473 15	$7,086 55	$23,559 70
Star No. 2	110	4 4	V	22	8	30	....	2	....	....	....	14,649	14,649	3,222 55	6,326 01	9,548 56
Air Line	100	5-6	V	16	3	19	118	2	....	4,120	2,077	2,197	8,394	3,572 60	938 68	4,511 28
Chandler	120	5-0	V	20	3	23	83	3	....	1,788	655	3,490	5,933	2,940 00	4,185 00	7,125 00
Big Four	*	7-0	V	32	7	39	220	4	2	....	....	32,356	32,356	15,402 02	4,921 30	20,323 32
Caledonia	†	7-0	V	38	7	45	210	4	4	919	743	20,000	21,662	11,901 13	3,931 97	15,833 10
DeForest	65	7-0	V	24	3	27	176	2	....	5,131	2,819	5,587	13,537	5,456 89	1,771 48	7 228 37
Goslee	87	4-4	V	Work	in	fewer	than	ten	men.							
Totals	....	....	....	198	38	236	....	23	8	11,958	6,294	114,813	133,065	$58,968 34	$29,160 99	$88,129 33
Totals in Block Coal Machine Mines	....	....	....	631	83	717	....	70	22	284,513	51,594	12,896	319,003	$247,493 80	$161,827 12	$409,320 92
Totals in Bituminous Machine Mines	....	....	....	1,852	267	2,119	....	272	50	549,498	392,334	585,151	1,526,983	649,831 46	445,022 04	1,094,853 50
Totals in Block Coal Hand Mines	....	....	....	1,707	145	1,852	....	138	31	932,116	136,068	94,911	1,163,095	620,243 95	244,389 56	864,633 51
Totals in Bituminous Hand Mines	....	....	....	4,665	535	5,200	....	452	171	997,915	572,552	1,673,515	3,243,982	1,675,248 24	799,287 09	2,474,535 33
Grand totals	....	....	....	8,858	1,030	9,888	....	932	274	2,764,042	1,152,548	2,366,473	6,283,063	$3,192,817 45	$1,650,525 81	$4,843,343 26

NOTE 1. The sign * indicates mines that are worked by slope.

NOTE 2. The sign † indicates drift mines.

NOTE 3. A great many of the machine mines reported work a number of pick men, but it was found impossible to have the product of machine and pick men reported separate.

COAL TRADE AND MINING CONDITIONS.

The condition of the coal trade in general has been better for the year 1900 than ever before in the history of the State. The activity in the investment of capital in this industry during the year just ended has likewise been unparalleled. In the year of 1899, only nine new mines were reported, while last year there was an enrollment of thirty-two additional mines, and only two mines abandoned, making a net increase for the year of thirty mines and being the largest increase therein of any year on record. With the seven new mines now ready for enrollment, the total enrollment of mines, exclusive of small mines to which the mining laws have no application, is one hundred and sixty-one.

The total number of tons of coal produced during the year 1900 is 6,283,063, exceeding the production of the year 1899 by 443,150 tons, or over seven and one-half per cent. This increase in production may surprise many persons engaged in this industry, as, in many localities, the mines were operated fewer days than in 1899. It will be remembered that during the summer of the last named year the mines south of the Baltimore and Ohio Southwestern Railroad were more or less involved in strikes, some of the larger mines of that coal field being practically idle for about six months, while in 1900, there was very little loss of time from this cause in any part of the State. This is the most important factor of this increase in production. The records of this Department show also that a larger number of men were engaged in this industry during the past year than in any previous year. The increase in the number of mines, too, contributed to the increase of production, though, as a rule, a new mine is not a large producer during the first year of its operation. The increase in the capacity of mines by reason of the use of improved machinery and appliances, such as electric haulage and mining machines, has also influenced production.

Judging from present prospects, there will be a considerable number of new mines opened in this State within the ensuing year, and the indications now are, that there will also be an increase in the production of coal. Much depends, however, upon the action of the joint convention of miners and operators, as to whether they will arrive at a satisfactory agreement for this year. It was said at the miners' convention, held at Indianapolis in January, that coal from Indiana had encroached upon and displaced last year 600,000 tons of Illinois coal in the Chicago market. If this statement be true, taking into consideration the fact that in parts of Illinois a lower

rate is paid for mining coal than in Indiana, that in no part of that State does the mining rate exceed the rate in this State, and that the distance is greater and the freight rate higher from the Indiana coal fields to the market than from those of Illinois, it is a high compliment to Indiana coal and indicates that this coal is superior to the coal of Illinois, and that it will probably continue to absorb more and more of the market now supplied by that coal.

Mine work in this State during the past year, taking the State as a whole, has been better than in 1899, but has been more distributed, both as to time worked and the number of mines affected. In 1899, a large number of mines lost a great deal of time by reason of strikes and disagreements, inuring to the benefit of the mines not so involved. Especially is this true of the coal field of the southern part of the State. While the mines in the central coal region of Indiana have not been operated as steadily last year as in 1899, especially in the Linton field, the mines in the southern coal field have been run a great many more days in 1900 than in the former year. Considering all conditions, mine workers are enjoying greater prosperity than ever before in the history of that industry. Gratuitous labor, called by the craft "dead work," has practically been abolished, being now performed by persons employed for that purpose; the hours of labor were never so short as now; and, considering the improved appliances and methods of mining, the wages now paid are higher than ever before, as will be seen by a reference to the wage tables in the reports of this department. Take for example the years 1899 and 1900. These tables disclose the fact that, while the aggregate tonnage for the latter year only exceeded the former by 443,150 tons, or seven and one-half per cent., the aggregate wages paid during the latter year exceeded that paid during the former year by $1,042,371, or approximately twenty-seven and one-half per cent., a net increase in the aggregate wages paid of twenty per cent. in one year. This increase in wages has not been confined to any particular class of mine workers, but extends to all kinds of such labor. A comparison of the agreement, as to prices, between the miners and operators for 1899, published in the last year's report of this department, and their agreement therefor for the past year, which is given below, will further verify this statement of increase of wages.

TERRE HAUTE AGREEMENT.

April 1st, 1900, to April 1st, 1901.

Pursuant to an agreement made between the Coal Operators and United Mine Workers of America, of Illinois, Indiana, Ohio and Pennsylvania, made at Indianapolis, February 2, 1900, the price of mining for bituminous coal in the State of Indiana shall be 80 cents per ton of 2,000 pounds, for screened lump coal, made over a standard screen, and 49 cents per ton of 2,000 pounds for run of mine. That further details in scale of prices for pick and machine mining in the State of Indiana for one year, beginning April 1, 1900, shall be as follows:

Pick Mining.

(Yardage.)

In entries 7 to 9 ft. wide, $1.66.

In entries 12 ft. wide the price shall be five-eighths of the regular price, or $1.03½. Entries shall not exceed 12 ft., it being understood that this applies to entry work only.

Break Throughs.

Break throughs and entries shall be paid for at entry prices. Break throughs between rooms when sheared or blocked shall be paid for at entry prices, but no break throughs shall be driven without the consent of the operators. Nothing herein shall interfere with the law governing break throughs.

Room Turning.

Room turning, $4.00.

Room necks to be driven 12 ft. in and widened at an angle of 45 degrees when so desired by the operator. Any distance in excess of above shall be paid for proportionately. When room necks are driven 12 ft. wide, price shall be five-eighths of regular price, or $2.50.

Machine Mining.

In entries 7 to 9 ft. wide, $1.19.

In entries 12 ft. wide five-eighths of price for narrow entries, or 74c. Narrow work after Punching Machines shall be sheared when demanded by the operator. Narrow work after the Chain Machine must be done in a workmanlike manner.

Break Throughs.

Break throughs between entries, same as entry prices. Break throughs between rooms shall be paid for at same price when similarly driven. This applies to width and not method of mining.

Room Turning.

Room turning, $3.00.

Room necks to be driven 12 ft. in and widened at an angle of 45 degrees when so desired by operators. Any distance in excess of above shall be paid for proportionately. When room necks are driven 12 ft. wide price shall be five-eighths of regular price, or $1.87.

Day Work for Punching Machines.

Machine cutting when paid for by the day shall be, for—

Machine runner	$2 82
Helper	2 22

Day Work, Chain or Cutter Bar Machine.

When paid for by the day shall be for machine runner	$2 67½
Helper	2 67½

Day work by machines shall apply only to defective work such as horse back, etc.

Price Per Ton for Machine Mining.

FOR PUNCHING MACHINE.

Screened Lump.—Runner, 9c; Helper, 8c; Loading, Shooting and Timbering, 45c; Total, 62c.

Run of Mine.—Runner, 5¾c; Helper, 5¼c; Loading, Shooting and Timbering, 28c; Total, 39c.

For Chain Machine.

Screened Lump.—Runner, 5¼c; Helper, 5¼c; Loading, Shooting and Timbering, 48c; Total, 58½c.

Run of Mine.—Runner, 3¼c; Helper, 3¼c; Loading, Shooting and Timbering, 30c; Total, 36½c.

Shovels shall be furnished by the operators, but when replaced the old shovels must be returned, and in case of careless breaking, or destruction by the miner, he shall pay for the shovel so destroyed.

Blacksmithing.

Price of blacksmithing shall be 1¼c on the dollar. Sharpening shall be done in a workmanlike manner and men shall not have to wait for their tools.

Day Labor

As provided in the Indianapolis agreement the advance on inside day labor shall be 20 per cent., based on the present Hocking Valley and Columbus inside day labor scale, with the exception of trappers, whose compensation shall be $1.00 per day.

GENERAL.

1. Where the coal is paid for mine run or screen coal basis, it shall be mined in a careful and workmanlike manner, and when loaded on the miner's car it shall be as nearly as possible free from slate, bone coal or other impurities. When a miner shall load and send out less than 5 per cent. of impurities in one car of coal he shall be docked the amount of impurities so sent out. Whenever he shall send out 5 per cent. or more of impurities in one car he shall be docked the amount of impurities so sent out, and shall be laid off from work for one day. Whenever he shall send out two cars on the same day, each containing 5 per cent. or more of impurities, he shall be docked the amount of impurities and laid off for two days. Whenever he shall send out three such cars in one day he shall be docked the amount of the impurities and laid off six working days.

2. The semi-monthly pay shall continue until the constitutionality of the law providing for weekly pay shall have been passed upon by the Supreme Courts of Indiana and of the United States.

3. The time of beginning work in the morning and the length of intermission at noon shall be considered a local question.

4. That the above scale is based upon an eight-hour work day; that it is definitely understood that this shall mean eight hours' work at the face exclusive of the noon time; six days in the week or 48 hours in the week, and that no local ruling shall in any way deviate from this agreement, or impose conditions affecting the same, but any class of day labor may be paid at the option of the operator for the number of hours and fraction thereof actually worked at the hour rate, based on one-eighth of the scale rate per day, provided that when men go into the mine in the morning they shall be entitled to two hours' pay whether the mine works or not, as provided in the above agreement for inside day labor; providing, further, that overtime of day labor shall be paid for at the same rate per hour.

5. Inside day work may be done upon idle days, and in case of emergency, on overtime.

6. Whenever any laborer working by the day in the mine shall become dissatisfied with his work or the price thereof, and shall demand that he be given work at mining coal within the mine, his demand for this change of labor shall only be acceded to by the operator after three days' notice of his desire to change, or in case other men can be obtained who will do this work in a satisfactory manner at the price herein agreed upon. Concerted action on the part of any class of labor in demanding a change of this nature shall not be granted, but shall be deemed a violation of this agreement.

7. It is agreed that if any difference arises between the operators and the miners at any mine a settlement shall be arrived at without stopping of work. If the parties immediately affected can not reach an agreement between themselves the question shall be referred without delay to a board of arbitration consisting of two operators selected by the operators interested, and two miners selected by District No. 11 of the United Mine Workers of America. In the event of these four being unable to reach a decision they shall select a fifth man, and the decision of the board so

constituted shall be final, but no miner or operator interested in the difference shall be a member of such board.

8. The duties of the Mine Committee shall be confined to the adjustment of disputes between the mine boss or superintendent and any of the members of the United Mine Workers of America working in the mine. In case they fail to agree they shall proceed to adjust the trouble by the selection of an arbitration board as provided in article 7 of this agreement. The Mine Committee shall have no other authority nor exercise any other control nor in any other way interfere with the operation of the mine.

9. That under no circumstances will the operator recognize or treat with the Mine Committee or any representative of the United Mine Workers of America, during suspension of work, contrary to this agreement.

10. The operator shall have the privilege of working a night shift for cutting coal with machines. All men so employed shall be paid 25 cents extra for each eight hours' work at night, in addition to the scale price per ton.

11. Work on driving entries and drawing pillars may be by double shift at the option of the operator.

12. It is further agreed that the operators shall offer no objection to the check-off for checkweighman and for dues for the Federation, provided that no check-off shall be made against any person until he shall have first given his consent in writing to his employer. This applies to all underground day work as well as miners.

W. D. VAN HORN,
President U. M. W. of A., District No. 11.

Attest: J. H. KENNEDY,
Secretary U. M. W. of A., District No. 11.

J. SMITH TALLEY,
President Bit. Coal Op. Assn. of Ind.

Attest: A. D. SCOTT,
Secretary Bit. Coal Op. Assn. of Ind.

LABOR TROUBLE.

As indicated in another part of the report, the past year has been remarkable for the absence of labor troubles, there being but one strike of a serious nature; that is, the engineers' strike. During the month of November, 1900, the Brotherhood of Hoisting Engineers held its annual convention at Springfield, Illinois, and, among other things, adopted a scale of prices and conditions for the government of hoisting engineers in Indiana and Illinois. In pursuance of the action of that convention, the hoisting engineers of the State of Indiana demanded from the operators of the State that, at mines hoisting five hundred tons of coal per day or more, there should be three engineers employed; that, at mines hoisting two hundred tons of coal per day, there should be two engineers employed, and

that, at mines hoisting fewer than two hundred tons of coal per day, there should be one engineer employed; that where three engineers were employed, the price paid for the services of such engineers should be $65.00, $75.00 and $90.00 per month, respectively, which, to the highest class of engineers, meant an increase in wages and a reduction of working hours. The operators refused to comply with this demand. In the counties of Vermillion, Parke, Vigo, Clay, Sullivan and Greene, the engineers, with but few exceptions, quit work, and for a time, it appeared as if the whole State would be involved in the strike; but, after a tie-up of the mines for six or eight days in the section mentioned, the engineers resumed work, without having received any concessions to their demand.

The following December, the miners in the Linton coal field demanded of the engineers that they join the organization of United Mine Workers of America, which, in effect, meant the destruction of the organization of the engineers. The engineers refused to comply with the request, and the miners in this coal field struck for the purpose of enforcing their demand, no other part of the State being involved. After a week of idleness, the miners resumed work pending an adjustment of the controversy at the next national convention of the United Mine Workers, when it is hoped a satisfactory agreement will be reached.

In addition to the above troubles, there have occurred numerous small strikes, usually involving only one mine, and seldom resulting in more than from one to four days' loss of time, none of them being of sufficient magnitude to justify special mention.

TABLE

Showing the Production of Coal in Tons of 2,000 Pounds in Indiana During the Year 1900, at Mines Employing More Than Ten Men, by Months and by Counties.

COUNTY.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Clay	122,137	116,063	123,194	139,848	148,785	114,463	88,238	103,242	110,196	113,648	197,656	119,793	1,497,677
Daviess	23,534	26,916	29,116	8,988	17,014	16,063	17,369	19,908	20,835	23,549	29,404	21,384	254,030
Fountain	3,276	3,437	3,537	1,837	2,206	4,189	4,848	4,260	4,258	3,596	2,387	3,809	41,640
Gibson	7,398	6,947	7,532	87	1,019	1,998	2,845	3,749	5,214	7,544	7,953	7,134	59,420
Greene	77,375	70,114	59,678	32,448	70,688	49,174	59,491	48,854	59,320	64,597	65,408	89,333	746,483
Knox	3,316	7,110	6,005	8,860	2,842	3,462	2,776	3,049	4,654	5,033	6,056	6,273	59,382
Martin	687	456	579	487	843	537	554	658	810	944	717	994	8,266
Parke	85,552	63,888	60,742	22,478	61,121	34,439	44,641	55,420	57,956	66,315	63,085	64,324	679,024
Perry	2,343	1,839	3,835	2,612	2,488	2,641	1,416	1,613	Strike.	906	912	2,885	23,480
Pike	25,044	18,989	25,706	12,985	11,895	12,921	14,006	10,824	28,764	28,222	33,167	27,281	249,804
Sullivan	87,696	78,940	42,078	34,874	47,319	39,720	29,027	70,686	70,574	82,917	66,118	98,729	748,678
Vanderburgh	16,705	16,595	15,167	10,934	8,553	8,570	11,553	14,322	17,195	18,475	17,580	17,363	172,562
Vermillion	57,489	65,927	71,748	89,031	65,841	38,310	45,506	45,519	65,272	70,897	63,558	72,251	751,349
Vigo	40,005	45,626	28,002	39,114	26,795	38,594	46,069	54,310	65,157	68,109	160,002	162,117	809,884
Warrick	21,496	17,177	16,045	13,873	10,927	8,567	10,466	13,551	16,263	17,229	18,211	17,579	181,384
Total	620,053	540,044	492,964	417,464	477,541	403,638	288,811	359,965	442,576	391,881	581,281	611,199	6,283,063
Estimated output of small mines													74,913
Grand total													6,357,916

TABLE

Showing the Wages Paid to Employes in Indiana, During the Year 1900, at Mines Employing More Than Ten Men, by Months and by Counties.

COUNTY.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Total.
Clay	$107,124 05	$100,109 09	$108,882 77	$48,124 19	$57,017 94	$69,324 47	$90,000 36	$103,539 53	$107,028 08	$104,013 70	$101,094 55	$115,573 71	$1,111,832 44
Daviess	18,080 94	16,153 82	17,479 45	8,109 46	14,967 64	13,390 35	15,611 21	18,958 20	19,806 68	19,023 16	21,846 33	18,055 41	201,482 65
Fountain	3,184 67	3,102 50	3,438 50	1,992 20	917 34	3,852 00	4,322 75	3,687 20	3,807 25	3,299 85	2,365 00	3,417 69	37,386 95
Gibson	4,372 98	4,084 40	4,294 11	514 47	4,128 22	2,274 53	2,592 46	4,221 67	4,121 59	5,743 95	5,748 79	5,266 33	43,663 50
Greene	41,386 81	38,013 16	42 061 96	25,933 58	29,464 41	31,712 89	32,447 83	39,116 76	41,358 45	57,652 40	42,553 55	57,352 92	484,084 72
Knox	6,007 78	5,263 19	14,872 72	2,643 01	2,713 72	2,865 96	3,331 67	3,338 55	5,347 72	4,215 86	4,671 42	5,423 41	50,695 01
Martin	495 00	344 00	379 00	344 00	622 00	407 41	425 00	659 00	685 00	738 00	715 00	990 00	6,823 41
Parke	65,609 68	59,247 59	63,684 80	24,645 18	42,835 69	36,455 54	43,434 84	37,433 89	54,447 29	66,490 51	54,549 66	62,284 78	611,119 45
Perry	1,985 82	1,530 72	1,893 82	538 98	564 87	575 32	811 14	664 24	182 87	494 01	881 36	,135 87	11,259 05
Pike	16,128 88	11.668 80	23,778 27	11,051 67	17,943 51	10,570 90	22,050 98	9,937 44	9,570 43	27,609 87	21,069 16	22,511 46	207,891 37
Sullivan	47,781 40	43,402 34	43,620 87	19,377 98	38,524 47	41,382 46	51,114 42	48,112 81	57,483 91	59,698 10	49,332 17	58,790 05	558,620 98
Vanderburgh	14,440 91	13,036 01	13,229 00	6,894 97	7,291 46	10,324 27	11,019 55	13,975 06	16,089 37	17,880 50	15,958 31	51,154 12	191,293 53
Vermillion ...	38,166 24	35,073 48	53,594 66	16,707 22	46,874 02	44,736 50	29,468 92	29,369 79	48,296 97	50,775 84	48,106 64	54,191 28	495,361 20
Vigo	68,606 18	59,256 12	65,711 99	42,590 35	58,212 73	51,731 64	62,923 55	52,862 55	53,849 06	67,405 09	67,325 02	73,503 08	723,977 37
Warrick	14,853 31	8,125 26	8,345 65	7,924 88	7,726 34	6,264 12	7,616 53	8,915 26	9,559 91	7,211 26	11,541 30	13,767 81	111,851 63
Total	$448,224 65	$398,440 48	$455,267 57	$217,392 14	$322 046 36	$330,368 36	$377,171 21	$373,791 95	$443,634 58	$492,271 77	$4,447,758 72	$543,417 92	$4,843,343 26
Estimated wages of small mines													39,680 92
Grand total													$4,883,024 18

NEW MINES.

During the year 1899, several new openings were made and partially equipped, from which some little coal was mined and sold to local trade; the number of persons employed, however, being too small to bring them under the law requiring inspection, no mention of them was made in the report for that year. The following is a description of these and all other new openings made during the year 1900, which are now subject to the mining laws of Indiana.

CLAY COUNTY.

GIFFORD MINE.

This mine is owned and operated by the Collins Coal Co., and is situate on the old Gifford farm three miles west of Brazil. This is one of the most desirable mining properties in Clay County, having an area of about fifteen hundred acres of coal land underlain with a seam of bituminous coal averaging four and one-half feet thick, the quality of which is said to be equal to the best Brazil block coal. The roof is hard black slate lying very uniform, and the bottom is a very hard fire clay.

The shaft was sunk and equipped in 1899 by Thomas Watson, who operated it on a small scale during that year, the product going to supply local trade in Brazil and surrounding country. The present company was organized during the past summer and built a switch one and three-fourths of a mile long to the mine from the C. & I. C. R. R., completing it about September 1st. Since that time the mine has been developed very rapidly, and at last report employed seventy-six miners.

JACKSON COAL AND MINING CO.'S CORNWELL MINE.

This mine is located one-half mile east of Cardonia on a coal switch on the north branch of the Vandalia R. R. The top and bottom block seams are both worked at this mine. The shaft was sunk to the top vein in the fall of 1899, the mine was equipped and commenced shipping coal in January, 1900, and the work of sinking to the lower vein was completed some time in September. The company is now sinking the second outlet or man-way.

FORTNER MINE.

This mine is owned and operated by C. Ehrlich. It is located on the site of the old Fortner or Fox Den Mine, which was worked out and abandoned in 1897. The coal seam worked is bituminous and of

good quality, ranging from three and one-half to four feet thick, and is reached by a shaft one hundred and thirty-eight feet deep. The shaft was sunk and partially equipped in 1899, but no coal of any note was mined until January of the following year. At present the mine employs about forty-five persons.

EUREKA NO. 4 MINE.

The Eureka No. 4 Mine is located one-fourth mile east of Carbon on the Big Four R. R., and is a part of the workings of the old Chicago Mine, which burned down in 1891. At that time the Chicago Mine was owned by the Brazil Block Coal Co., and, as it was thought to be nearly worked out, they did not rebuild it, but later sold the property to the Eureka Block Coal Co., which owned the adjacent coal lands. The latter company commenced to sink in the fall of 1899, and completed the shaft to the top vein in the spring of 1900. Very little coal was mined, however, until the following September. Since that time about forty miners have been employed and the mine has a capacity of about 200 tons per day. The work of sinking to the lower vein has lately been completed, and the company is now taking out the water preparatory to working both seams, which are said to be an excellent quality of block coal.

LAWTON MINE.

The Lawton Mine is located one-half mile south of Fontanet on a coal switch from the Diamond Mine switch and is a new addition to the Coal Bluff Mining Co.'s mining property. It was completed and ready for shipping coal in the latter part of December, 1900.

GLEN MINE.

This mine is located one and one-half miles east of Coal Bluff on the C. & I. C. R. R., and is also owned by the Coal Bluff Mining Co. Sinking was commenced in August, and the mine was completed and ready for operation about the same time as the Lawton Mine. Information regarding both of these mines is very meager, owing to there having been no reports nor any inspections made of either of them.

DAVIESS COUNTY.

BLACK DIAMOND MINE.

This mine is owned by the Black Diamond Coal Co., and is located about one mile south of Washington near the Petersburgh Rock Road. It was opened in 1899, but was worked only on a very small

scale during that year and a greater part of 1900. The first report made to this office was for the month of November. At that time fifteen persons were employed. The product of this mine is sold only to local trade.

GREENE COUNTY.

WILD CAT MINE.

The Wild Cat Mine is owned and operated by the L. T. Dickerson Coal Co., and is located near the corporate limits of the town of Linton on the northwest side thereof. This is an extra well equipped mine for handling coal, having double first motion engines, self-dumping cages and other modern appliances. Ground was broken in sinking the shaft last April, and the output of the mine for December reached a capacity of more than six hundred tons per day. This rapid development indicates that it will be one of the largest coal producers in the State within a very short time. The second outlet, or man-way, is now nearly finished, and the mine will then be in compliance with all the requirements of the law.

ISLAND VALLEY NO. 2 MINE.

This mine is located four miles west of Linton on the I. & V. Branch R. R. It was opened by the Island Valley Coal Co. in 1899, but for some reason it was not equipped, nor was the mine switch laid, until September, 1900. The vein worked here is "Coal VI," which averages five and one-half feet thick and is exceptionally free from faults and impurities which characterize this coal seam. An inspection of the mine was made during the month of November, and it was found to be in good condition, employing about forty persons.

ISLAND VALLEY NO. 3 MINE.

The Island Valley No. 3 Mine is also owned and operated by the Island Valley Coal Co. It is located two and one-half miles southwest of Linton on a coal switch three-fourths of a mile long connecting with the S. I. R. R. The shaft was sunk in the latter part of 1899, and the company began shipping coal in March, 1900. Two inspections have been made of this mine within the past year, one in the month of March and the other in September, at which time the mine was found to be in good condition.

BLACK CREEK MINE.

The Black Creek Mine is located northwest of Linton one and one-half miles, on a coal switch from the S. I. R. R. This is an electric machine mine, the equipment of which is very complete, having double first motion hoisting engines of the latest improved pattern, self-dumping cages and all other conveniences incident to the handling of a large output of coal. The mine possesses many advantages not common in all mines. As a result of considerable drilling, the shaft was located and sunk in a basin, the main entries rising both north and south from the shaft bottom, thus affording natural drainage as well as the additional advantage of a down-hill haulage, which are two of the most important factors in the production of coal. The seam mined is "Coal IV," which averages about four feet nine inches in thickness overlain with a hard gray slate roof of excellent quality, and has a very hard sand-grit bottom.

HOOSIER MINE.

This mine is owned and operated by the Hoosier Coal Co., and is located about two and one-half miles northwest of Linton on a coal switch from the S. I. R. R. The company was organized in June, 1899. The shaft was located and sinking begun October 7th following. Coal IV was found at a depth of one hundred and thirty-three feet, but had so changed in formation and general appearance that it was not believed to be "Coal IV." This coal, as shown in another part of this report, has an average thickness of five feet at nearly all of the Linton mines, also a gray shale roof; while at the Hoosier Mine, the coal thins to three feet seven inches and the roof changes to a hard sandstone. The bottom, though somewhat harder, is of the same character as that found in the Linton mines. This sudden change in conditions puzzled the mine management as well as many others, and they finally decided that "Coal IV" would be found at a lower depth. The shaft was then sunk to what is now admitted to be "Coal III." The coal here was six and one-half feet thick, but was divided into two benches by a band of "white top" or "sand clod," one foot of coal overlying the "clod" and five and one-half feet of coal beneath it. An effort was made to open and work the lower bench of this seam, but it was found impossible to hold the "clod" for roof, and the expense of handling three and one-half feet of dirt would be so great that the coal could not be mined and marketed in competition with more cheaply produced coal. They abandoned this seam July 1st, 1900, and began developing the top vein. An in-

spection was made in December. At that time considerable entry had been driven and several rooms turned, and there were about twenty-five persons employed in the mine. Mining is done by electric chain machines, and the mine is exceptionally well equipped for handling a large output of coal.

Knox County.

THE KNOX COUNTY COAL CO.'S MINE

The Knox County Coal Company was organized in the spring of 1900 and has opened an excellent mining property known as the Knox Coal Mine, located one mile west of Bicknell on the main line of the I. & V. R. R. The seam mined here is "Coal VI" and averages four feet four inches in thickness, which is somewhat thinner than this seam is usually found, but it is said to be of extra good quality. The shaft is seven feet eight inches by fiften feet in size and one hundred and three feet deep. No expense has been spared in equipping it as a first-class mine. The coal will be mined by hand for the present, but it is said that the company is seriously considering the advisability of using electric mining machines in the near future.

Pike County.

ABERDEEN MINE.

The Aberdeen Mine is located five and one-half miles east of Oakland City on a coal switch from the Air Line R. R., and is owned and operated by the Aberdeen Coal Co. The shaft is eight by sixteen feet in size and forty-one feet deep; the seam mined is "Coal IV" and is said to be equal in quality to the best bituminous coal in the State. Mining at present is done by hand, about forty-two miners being employed, but the company is now making arrangements to put in electric machines.

ALDEN MINE.

This mine is owned and operated by the Alden Mining and Mercantile Co., and is located one mile from the railroad south of the town of Winslow. The coal tipple is built on a railroad siding within the corporate limits of Winslow and the coal is hauled from the mine to the tipple over a tram road. The seam mined is very similar to that mined at Ayrshire No. 3 Mine, though the vein is six or eight inches deeper than at the Ayrshire. The mine was opened in 1899 and worked as a wagon mine, the product being sold to local trade.

The tram road was built during the summer of 1900, and it became a shipping mine in October. On inspection December 12th, it was found in good condition, employing fourteen persons.

AYRSHIRE NO. 4 MINE.

This is a new addition to the David Ingle Coal Co.'s coal properties, and is situate about one mile east of their No. 3 mine. The mine is opened by a drift and is exceptionally well located, having good drainage, excellent roof and bottom. The coal seam is about four feet eight inches thick and in quality is about the same as that of No. 3, which is said to be the best bituminous coal in Indiana. The work of opening the mine was commenced in June, 1900, and shipping was begun in September following. An inspection was made December 12th, when the mine was found to be in good condition and employing twenty-five persons.

JAXON MINE.

This mine is worked by a slope and is located about half way between Sophia and Ayrshire on a coal switch from the Air Line R. R. It was opened in the latter part of 1899 by William Jackson and began shipping coal January 1st, 1900. Jackson continued operating it until the following June, when he sold the property to David Ingle. At the time the last inspection visit was made (December 12th, 1900), the mine was found idle. At that time it furnished employment to about thirty persons.

PERRY COUNTY.

SULPHUR SPRINGS MINE.

This is a small mine owned and operated by the American Cannel Coal Co., and is located in the hill back of Cannelton. The mine is worked by a slope and furnishes employment for from about twelve to fourteen miners. The product is sold to local trade in the city of Cannelton and the surrounding country.

SULLIVAN COUNTY.

PHOENIX NO 3 MINE.

This mine is located one-half mile west of Phoenix No. 1 Mine, and is owned and operated by the New Pittsburg Coal and Coke Co. The mine is opened by a slope some three hundred feet in length, up which the coal is hoisted by rope. Mining is done here partly by

hand and partly by machines, the Harrison Compressed Air Puncher (three in number) being used; the power is furnished from No. 1. The mine employs about forty persons and has a capacity of two hundred and fifty tons per day.

PHOENIX NO. 5 MINE.

This mine is also owned and operated by the New Pittsburg Coal and Coke Co., and is located one-half mile north of No. 3. It is worked by slope, the hoisting being done with a third rail sprocket motor. The mining is done here entirely by machines of the same style as those used in No. 1 and No. 3, and like No. 3, the power is furnished from No. 1.

VIGO COUNTY.

GLEN OAK MINE.

The Glen Oak Mine is owned and operated by the Torrey Coal Co., and is located one-half mile south of Grant on a coal switch from the C. & I. C. R. R. The seam mined is "Coal VI," and has an average of six and one-half feet in thickness. It is worked by a shaft eight by sixteen feet in size and fifty feet deep. It is the intention of the company to develop a mine here whose capacity will be second to none in the State. The shaft was commenced in July and was completed and equipped with the mine switch laid ready to ship coal in the latter part of September. About twenty miners were employed driving entry until September 15th, when the mine suspended operations for the purpose of putting in electric chain mining machines. Two machines are in use at present, but this number will be increased as the mine is developed.

RED BIRD MINE.

This mine is owned and operated by the Fanore Coal Co., and is located one mile west of West Terre Haute on the Vandalia R. R. The shaft is ninety feet deep and six by seventeen feet in size. The coal seam worked is "Coal VI" and is of an average thickness of six feet. The shaft was commenced in April, 1900. The company began shipping coal in October following. At last report they were employing twenty persons.

CHICAGO MINE.

The Chicago Mine is owned and operated by the Pfaelzer Coal Co., and is located one mile east of Coal Bluff on the C. & I. C. R. R. This is a mine worked by a slope opened to "Coal VI," which averages about five and one-half feet thick.

The first report made from the mine was for the month of June. At that time forty-three persons were employed. The December report, however, shows this force to have been increased to seventy-one, and the daily capacity of the mine is about three hundred tons.

KOCH MINE.

This mine is owned and operated by George Koch. It is a small slope mine located a short distance south of Coal Bluff on the C. & I. C. R. R. The mine has just recently employed a sufficient number of miners to bring it under the law. The first report made to this office was for the month of November. At that time eighteen persons were employed.

ROYAL MINE.

This mine has lately been sunk and equipped by the Seelyville Coal and Mining Co. The first report was made from it to this office for the month of November. They have also completed another new mine in the vicinity of Seelyville, which will report for December. No inspections, however, have been made of either of these mines; therefore information regarding them is very meager.

VERMILLION COUNTY.

OAK HILL MINE.

The Oak Hill Coal Co. was organized in 1899, and began sinking the shaft in the fall of that year. The shaft was completed, equipped and commenced shipping coal in March, 1900. The shaft is situate about half-way between the Brouillet's Creek Nos. 4 and 5; the coal seam mined is "Coal VII," or what is known through the Clinton field as the top vein. Two inspections were made of the mine in 1900, and it was found in excellent condition at both visits. A second outlet or man-way has been provided by means of a slope, which places the mine in compliance with the law in every respect.

BROUILLET'S CREEK NO. 5 MINE.

This mine was opened during the year 1900. It is located about three-fourths of a mile south of their No. 4 mine. The shaft was commenced in the spring of 1900, completed and began shipping coal in October following. An inspection made that month found the mine in good condition.

Warrick County.

BIG FOUR MINE.

This mine is owned and operated by the Big Four Coal Co., some of whose members were the former operators of the Gough Mine, which was worked out and abandoned early in 1899. This company was organized in 1899 and began opening the Big Four Mine in the fall of that year. The work of sinking the slope was completed and the mine equipped ready to ship coal by January 1st, 1900. The mine is located one-half mile east of Boonville on the Air Line R. R. and is the largest producer in that part of the State. At the last report, it furnished employment to forty-one miners.

ABANDONED MINES THAT WERE REOPENED IN 1900.

The Rodgers Mine.

This, probably, is the oldest mine in Pike County, having been opened, as near as could be learned, about the year 1870 by the Rodgers Brothers, who operated it until 1881, when for reasons unknown, it was abandoned and allowed to fill with water. It is said that the pumps, mine cars, track and everything was left in the mine the same as when it was in operation. The S. W. Little Coal Co. leased the property in November, 1899, and began taking out coal from the old drift which had been used as a second outlet or man-way when the shaft was in operation. Since that time they have drained nearly all of the water out of the hoisting shaft by means of a ditch some twenty-two feet deep and one-fourth of a mile long, connecting with the old water shaft and extending across the low ground west of it. It is thought that, after the water is taken out of the shaft, they will rebuild the tipple and equip the mine anew.

The Petersburg Mine.

The Petersburg Mine near Petersburg in Pike County, abandoned by the J. Wooley Coal Co. in 1898, was re-equipped by the same company in the spring of 1900, and it is now being operated with fairly good success.

The Goslee Mine.

The Goslee Mine, in Warrick County, near Chandler on the Air Line R. R., abandoned in 1890, was re-opened and equipped by J. S. Goslee about September, 1900.

THE LYFORD No. 2 MINE.

This mine was burned down in 1896 and has remained idle since that time. The present company, the Wabash Valley Coal Co., began cleaning it up in October, 1900, and will have it ready for operation, February 1st, 1901.

ABANDONED MINES.

The following named mines were exhausted and abandoned in 1900:

THE LOUISE MINE.

Located near Center Point in Clay County, owned and operated by the Crawford Coal Co., was abandoned in June of the above year.

THE SAN PEDRO MINE.

Located near Staunton in Clay County, owned and operated by the Jos. Sommers Coal Co., was abandoned about August 1st, 1900.

WILSON'S No. 4 MINE.

Located at Washington, Daviess County, was abandoned in the latter part of June on account of water coming into the mine from the old Sulphur Springs Mine, into which the workings of No. 4 were driven about that time.

THE STURM MINE.

Located at Silverwood in Fountain County, owned and operated by the Silverwood Coal Co., reduced its force to less than ten men who were employed drawing pillars, preparatory to abandoning the mine.

TABLE.

Names of Mines Using Mining Machines, Number and Kind of Machines Used, and Geological Numbers of Coal Seams Mined; Also Those in Which the Different Kinds of Mechanical Haulage is Used, Giving the Number and Kind of Motors in Use, and the Power by Which the Machines and Haulage is Driven; Also the Estimated Cost of Machines and Haulage Equipments.

NAME OF MINE.	Geological Number of Coal Seam.	Number of Machines.	Kind of Machines.	Power.	Cost.	Haulage.	Number of Motors.	Power.	Cost.
Brazil Block, No. 1	IV	10	Chain	Electricity	$15,000	3d rail motor	2	Electricity	$3,500
Brazil Block, No. 8	III IV	11	Chain	Electricity	24,000	3d rail motor	1	Electricity	2,050
Brazil Block, No. 11	III	7	Chain	Electricity, power from No. 8	8,200	....	....	....	....
Diamond, No. 3	III	4	Chain	Electricity, power from No. 5	....	....	....	....	....
Brazil Block, No. 10	III	5	Chain	Electricity, power from No. 8	5,450	....	....	....	....
Diamond, No. 5	IV	4	Chain	Electricity	9,500	....	....	....	....
Briar Hill	IV	3	Puncher	Compressed air	7,100	....	....	....	....
Cabel, No. 9	VI	3	Chain	Electricity	9,540	3d rail motor	2	Electricity	3,700
Island, No. 1	IV	14	Puncher	Compressed air	14,000	Tail rope Tail rope	....	Steam Steam	2,500 3,000
Island, No. 2	IV	15	Puncher	Compressed air	21,000	3d rail motor	1	Electricity	4,240
Summit, No. 2	IV	6	Chain	Electricity	11,540	....	....	....	....
Hoosier	IV	1	Chain	Electricity	5,870	....	....	....	....
Black Creek	IV	3	Chain	Electricity	7,840	....	....	....	....

TABLE—Continued.

NAME OF MINE.	Geological Number of Coal Seam.	Number of Machines.	Kind of Machines.	Power.	Cost.	Haulage.	Number of Motors.	Power.	Cost.
Parke, No. 8	VI	16 4	Puncher Chain	Compressed air Electricity	23,000 8,000	Gravity, single rope		Steam	1,300
Cox, No. 3	VI IV	16	Puncher	Compressed air	26,000	3d rail motor	2		3,600
Mecca, No. 1	III					Traction motor	1	Electricity	4,700
Brazil Block, No. 12	IV III	9	Chain	Electricity, power from No. 8	10,000	3d rail motor	1		
Hartwell	V	1	Chain	Electricity	5,840				
Hymera	V	7	Chain	Electricity	11,000				
Phoenix, No. 1	V	19	Puncher	Compressed air	26,000	Traction motor	1	Electricity	5,800
Phoenix, No. 3	V	1	Puncher	Compressed air, power from No. 1	450				
Phoenix, No. 5	V	2 1	Puncher Puncher.	Compressed air, power from No. 1	900				
Star City	VI	8 3	Chain Puncher.	Electricity	12,540	3d rail Spr'ket motor	1	Electricity	2,200
Shelburn	VI	2	Chain	Compressed air	15,000				
Dugger	VI	5	Chain	Electricity	9,000	3d rail motor	2	Electricity	3,900
Ingleside	VI	2	Chain	Electricity	5,500				
Jackson Hill, No. 1	VI	14	Puncher	Compressed air	20,000				
Jackson Hill, No. 2	VI	6	Chain	Electricity	11,540				
Bunker Hill	VI	3	Chain	Electricity	6,500				

Sunny Side	V	11	Puncher	Compressed air	20,000				
Ingleside	V					Tail rope		Steam	2,500
		2	Chain	Electricity	7,600	Tail rope		Steam	1,000
Parke, No. 10	VI	21	Puncher	Compressed air	25,000	3d rail motor	1	Electricity	1,850
Ray	VI	10	Puncher	Compressed air	14,000				
Diamond	VI					Tail rope		Steam	1,500
Glen Oak	VI	2	Chain	Electricity	6,540				
Wooley Big Vein	V	5	Puncher	Compressed air	10,000				
Chandler	V					Tail rope		Steam	2,500
Total		256			$413,450		15		$49,840

IMPROVEMENTS.

There has been an unprecedented amount of improvements in the mines of the State in the past year, in the way of haulage plants, mining machines and other general improvements. The monthly reports from the various mines of the State show that the sum of $56,424.50 has been expended for this purpose, and it is quite possible that a large amount of money has been expended in minor improvements of which no report has been made. The more important improvements and those involving large expenditures are noted herein.

The Diamond Block Coal Company of Clay County has installed electric mining machines at its No. 3 and No. 5 Mines, changing the value of these properties very considerably.

The Brazil Block Coal Company has equipped its No. 11 Mine in Clay County and its No. 12 Mine in Parke County with electric mining machines; the latter mine has also been furnished with a third rail motor haulage system.

The Mutual Mine, owned by the Mutual Mining Company, is located about one mile from the track of the B. & O. S. W. Railroad, in Daviess County. The coal from this mine was formerly conveyed to the railroad by means of a tramway; but the company has now built a switch to the mine and has also constructed a new tipple and made other improvements, facilitating the marketing of its coal.

The Island Coal Company has fully equipped its No. 2 Mine, in Greene County with a third rail motor haulage plant, which will, no doubt, increase the capacity of the mine as well as reduce the cost of the production of coal.

The Prospect Hill Coal Company, operating the Prospect Hill Mine in Knox County, has reconstructed the tipple and coal bins at the mine. The product is sold exclusively to local trade and marketed in wagons. The new improvements will greatly facilitate the loading of wagons, and thus increase the capacity of the mine.

The Parke County Coal Company has installed in its No. 10 Mine in Parke County electric mining machines, and has also equipped the mine with a third rail motor haulage.

The Phoenix No. 5 Mine in Sullivan County, owned by the New Pittsburgh Coal and Coke Company, has been equipped with the Morgan third rail sprocket motor for hauling the coal from the bottom of the slope to the tipple.

Crowder and Sexton, operators of the Bunker Hill Mine in Sullivan County, have fitted out the mine with electric mining machines and an electric pump. They have also rebuilt the tipple and installed new

Prox and Brinkman cages, putting the property in first-class condition.

The Indiana-Chicago Coal Company has placed a third rail motor haulage plant in the Dugger Mine in Sullivan County, placing it among the best improved mines in the State.

The Green Hill Coal Company has constructed a switch from the railroad to the Green Hill Mine in Sullivan County, owned and operated by it.

Mine No. 3, of the Brouillet's Creek Coal Company, located in Vermillion County, has a deep hoist. The company has installed new Litchfield, first motion, double engines of the latest improved patterns at this mine, and removed the old engine to its No. 5 Mine.

The Chandler Mine in Warrick County, owned by J. A. Brian, has been equipped with a tail rope haulage system and other improvements.

The S. W. Little Coal Company has improved its mine known as Little's, by rebuilding the tipple and equipping it with new Prox and Brinkman cages, putting it in condition for loading more coal.

The Sunnyside Mine in Vanderburgh County, owned by the Sunnyside Coal Company, has been improved by the building of several additions to the tipple for the purpose of facilitating the hauling of coal.

EXAMINATIONS.

Examinations of applicants for certificates of competency to serve as mine bosses, fire bosses and hoisting engineers have been held in the city of Terre Haute at three different times during the year of 1900, and the following table gives the result of each examination:

DATES.	APPLICANTS.			PASSED.			FAILED.		
	M.B.	F.B.	H.E.	M.B.	F.B.	H.E.	M.B.	F.B.	H.E.
Terre Haute, March 21	25	......	27	15	......	14	10	......	13
Terre Haute, June 29	8	......	23	2	......	9	6	......	14
Terre Haute, October 16	19	......	19	12	......	12	4	......	5
Total	52	......	69	29	......	35	20	......	32

The following is a list of the names and addresses of persons who passed at the above examinations, and to whom certificates of competency have been granted:

MINE BOSSES.

John H. Crabb, Burnett.
James Peel, Cardonia.
Alec G. Murdock, Cardonia.
Herman Rose, Littles.
James T. Jones, W. Terre Haute.
George R. Moore, Seelyville.
John T. Price, Washington.
Henry Osha, Washington.
Simon Grill, Washington.
James H. McKenna, Washington.
Reub Small, Clinton.
James A. Erwin, St. Marys.
Ralph Thomas, Center Point.
M. D. West, Cloverland.
William L. Smith, Ayrshire.
Oscar Busler, Coxville.
Charles F. Hill, Coal Bluff.
Thomas McCrae, Clinton.
Victor Allais, Montezuma.
Ellis G. Hooper, Bicknell.
W. F. Decker, Burnett.
William Davison, Hymera.
John Jones, Bicknell.
James A. Erwin, St. Marys.
Frank Sharer, Brazil.
Thomas Morris, Brazil.
John Dagon, Brazil.
James Devonald, Burnett.
William Small, Linton.

HOISTING ENGINEERS.

J. B. Gustin, Shelburn.
Ed Britzuis, Newburgh.
John E. Jones, Linton.
Marion Beckett, Hymera.
Herman Sauer, Dugger.
Philip Stevens, Knightsville.
James Donald, Sullivan.
Frank Dare, Dugger.
Orval Ham, Linton.
Terry Ring, Hymera.
William T. Hopkins, Carbon.
John A. Beck, Sullivan.
William T. Neal, Hymera.
Purdy C. Pullis, Hymera.
Willard Fox, Bicknell.
W. F. Maddox, Linton.
B. M. McNabb, Linton.
Grant Rawson, Terre Haute.
John F. McFerran, Evansville.
J. L. France, Gleezen.
William F. Houzer, Turner.
C. L. Wilson, Seelyville.
Robert J. Stephens.
Elmer Coleman, St. Bernice.
Thomas J. Hillburn, Bicknell.
Otis Collins, Bicknell.
Nat Hagerman, Linton.
Charles Cummins, Hymera.
Jessie Walter Marshal, Clay City.
Charles John Davis, Newport.
Henry Carrell, Clay City.
George Grenier, Edwardsport.
L. D. Ferguson, Marco.
M. McMorrow, Brazil.
James McClelland, Brazil.

NOTES.

1. There were no applicants for fire boss certificates at any of the above examinations, as shown by the above table.

2. The question will probably arise in the minds of some, why the examinations of 1900 were all held in the city of Terre Haute while there are three other cities named by statute where examinations may be held. It may be well to state in explanation thereof that a very large per cent. of the applicants at these examinations resided in Clay, Vermillion, Sullivan, Greene and Vigo counties. Terre Haute is centrally located with reference to all these counties

and there are railroads leading from each of them directly to that city, making it more convenient and accessible to the whole thereof than any other point. The number of applicants for examination from the south part of the State was so small in proportion to the whole number interested that, on the principle of accommodating the largest number of persons, it was thought just and fair to hold all of the examinations at the place named.

SERVICE CERTIFICATES.

Certificates of service to serve as mine bosses, fire bosses and hoisting engineers have been granted to the following named persons during the year 1900:

Hoisting Engineers.

Lincoln Foster, Evansville.
Charles Gilmour, Alum Cave.
George M. White, Vincennes.
Peter Andrews, Clay City.
Mark Wilson, DeForest.
Albert Clark, Alum Cave.
William Nash, Clay City.
Charles Nash, Clay City.
Robert Lauder, Boonville.
J. V. Gustin, Shelburn.
Harry Fuller, West Terre Haute.
Dallas Hickman, Evansville.
Robert Gough, Boonville.
John Black, Fontanet.
John A. Powell, Clay City.
Lewis Stock, Boonville.
William Wooley, Boonville.
John M. Walker, Evansville.
H. R. McClelland, Clinton.
Bert Dunlap, Clinton.
William Moore, Silverwood.
H. W. Johnson, Brazil.
Lewis McPherson, Ehrmandale.
John Harth, Clinton.
Hugh Shirkie, Clinton.
Charles Woods, Evansville.
George L. Harper, Linton.

Mine Bosses.

Walter Witman, Silverwood.
George Watkins, West Terre Haute.
Jesse Simmons, Evansville.
Samuel J. Wilton, Carbon.
John Price, Shelburn.
William Miller, Brazil.
Walter Phillips, Lyford.
Thomas Reese, Carbon.
Moses Bolin, Cannelton.
Joseph Harris, Linton.
William Tweezel, Linton.
William Huber, Chandler.
Robert Harkes, Coal Bluff.
Jackson C. Wagner, Knightsville.
Samuel Ogdon, Saxville.
Thomas Bingam, Heckland.
Thomas E. Maxwell, Brazil.
James W. Lewis, Burnett.
Garry Calahan, Petersburgh.
Hugh Shirkie, Clinton.
James Stuart, Alum Cave.
Doss A. Lenning, Coal City.
Josiah Hodges, West Terre Haute.
Reinholt Miller, Brazil.

Fire Bosses.

J. H. Erwin, Farmersburgh.

TABLE

Showing Names of Owners and Addresses, Number of Men Employed, Tons of Coal Produced and Wages Paid in Small Mines.

CLAY COUNTY.

Names of Owners.	Addresses.	Number Men Employed.	Tons.	Wages.
N. H. Haskins		6		
Samuel Adamson	Knightsville	6 to 8		
Frank Pique	Brazil	3 to 5		
Marih Row	Howsville	4	60	Not reported.
Weaver Coal & Clay Co	Brazil	4		$1,0 6 80
Whitmarsh & Price	Cardonia	20	5,752	Not reported.
Excelsior Clay Works Co	Brazil			
John Marks	Cardonia	4		
F. V. Burris	Coffee	2	300	$300 00
Benjamin Snell	Harmony	6		

DAVIESS COUNTY.

Names of Owners.	Addresses.	Number Men Employed.	Tons.	Wages.
Marthie A. Raymond	Washington	3		Not reported.
Shell Wallace	Washington	10	700	$760 00
D J. Ragsdale	Washington	6	1,507	1,655 50
Grant Stoy	Raglesville	6	900	720 00
George W. Browning	Epsom	5	80	100 00
Elijah S. & Jno. W. McGurd	Epsom	5	70	93 00
O. M. Cosner & J. A. Overton	Raglesville	16	2,000	1,280 00

MARTIN COUNTY.

Names of Owners.	Addresses.	Number Men Employed.	Tons.	Wages.
H A. Stephen	Shoals	2	500	$435 00
Killion Hotz	Dover Hill	4	320	240 00
Janson Chenowch	Shoals	9	4,000	2,400 00

OWEN COUNTY.

Names of Owners.	Addresses.	Number Men Employed.	Tons.	Wages.
Mitten & Colenbaugh	Coal City	7	1,177	$979 57
Jacob Hoffer	Harristown	3	1,900	

PARKE COUNTY.

Names of Owners.	Addresses.	Number Men Employed.	Tons.	Wages.
Theodore Shears	Bridgeton	5	100	$60 00
John Perrin & Sons	Catlin	10	4,288	3,500 00
W. H. Leonard & D. M. Adams	Rosedale	8	300	Not reported.
Caulwell Bros	Rockville	9		

PERRY COUNTY.

Names of Owners.	Addresses.	Number Men Employed.	Tons.	Wages.
John LeMain	Lincoln City	3 to 5	240	$232 00
Bergenroth Bros	Troy	14	6,234	5,176 46

PIKE COUNTY.

Names of Owners.	Addresses.	Number Men Employed.	Tons.	Wages.
Andrew Sanders	Petersburgh	1 to 2	500	$150 00
Elias Vaughan	Littles	3	1,200	49 80
William Sorgins	Winslow	2	160	125 00
Charles W. Bradfield	Petersburgh	4	700	Not reported.

FOUNTAIN COUNTY.

Names of Owners.	Addresses.	Number Men Employed.	Tons.	Wages.
Gicamo Berto	Coal Creek	3	1,000	$600 00
Tiley & Son	Silverwood	2	200	160 00
Marion E. Swim	Silverwood		230	
Thomas W. Tiley	Covington	15	1,600	1,460 00

GREENE COUNTY.

J. O. Pate	Switz City	5 to 10		Not reported.
Frank Woodhouse	Newberry	4	568	$336 47
Kates & Holder	Lyons	2 to 5	842	673 60
Joseph Boles	Bloomfield	5	700	600 00

KNOX COUNTY.

John William Atkinson	Edwardsport	4	952	$250 00
Beusinger & Marutz	Freelandville	4	1,020	433 00

SULLIVAN COUNTY.

W. T. Wilson	Jackson Hill	6 to 8	400	Not reported.
George Ward	Pleasantville	6 to 8		$2,300 00
L. S. Eaton	Sullivan	10		
William McClanahan	Jackson Hill	2	1,000	$700 00

VERMILLION COUNTY.

Sam Gerard	Cayuga	7	994	$687 50

VIGO COUNTY.

Henry Rentschler	Hausertown	3		
George Koch	Coal Bluff	4	7,560	$5,324 75
Charles Stuart	Coal Bluff	1 to 3	235	93 65
Jesse S. Winn	Coal Bluff	5	59	Not reported.
G. W. Bennett	West Terre Haute	6 to 8		
James A. Erwin	St. Marys	4 to 8	3,006	$2,768 70

GIBSON COUNTY.

G. W. Bird	Francisco	6	5,153	$3 940 00
John D. Johnson	Oakland City	5	1,416	1,908 93

WARRICK COUNTY.

J. A. Goslee	DeForest	12	1,100	$875 00
Louis Stock	Boonville	5	2,524	2,344 00
Sargent Bros	Newburgh	10	3,000	1,000 00

Total number of small mines reporting	56
Total number of miners reported from small mines	321
Total number tons of coal reported from small mines	74,918
Total amount of wages reported small mines	$39,680 92

An effort to obtain reports from small mines for the year 1900 has been made, but no very satisfactory results have been obtained. Over three hundred circulars have been sent out to small mine operators asking for data, but only the above number have complied with the request, and it will be noticed that some of those reporting have not reported wages in some instances while others have not reported tonnage.

INDIANA MINES.

Following is a list of mines which were in active operation on January 1, 1901, the person in charge of each mine, as shown by the December (1900) reports of the mine bosses:

CLAY COUNTY.

Mine.	Mine Boss.	Address.
Brazil Block No. 1	John Bolin	Brazil.
Monarch	James King	Brazil.
Diamond No. 3	Jas. Cuthbertson	Brazil.
Gladstone	W. P. McQuade	Brazil.
Brazil Block No. 11	James Burt	Diamond.
Brazil Block No. 8	Henry Payne	Brazil.
Pratt	H. W. Jenkins	Perth.
Eureka No. 2	W. T. Hopkins	Carbon.
Eureka No. 3	Jno. Somers	Carbon.
Rob Roy	James Dunlap	Brazil.
Dewey	Jno. Cox, Sr.	Brazil.
Gart No. 5	A. Gilmour	Cardonia.
Gart No. 3	Geo. Doidge	Brazil.
Crawford No. 4	Sam'l Lindsey	Hoosierville.
Columbia No. 4	T. Thompson	Hoosierville.
Columbia No. 5	M. Hoffman	Asherville.
Cornwall	Moses Marks	Cardonia.
Crawford No. 5	Walter Knox	Asherville.
Briar Hill	Alex. Ferguson	Clay City.
Markland	Peter Andrew	Clay City.
Harrison No. 2	Chas. Nash	Clay City.
Harrison No. 3	Chas. Nash	Clay City.
Klondyke	J. Ehrlich	Staunton.
Silverwood	William Myers	Turner.
Crawford No. 3	William Printz	Brazil.
Diamond No. 5	D. J. Evans	Brazil.
Brazil Block No. 10	Wm. McBeth	Perth.
Cloverland	George Donie	Brazil.
Pearl	Robert Jenkins	Brazil.
Fortner	Newton Braum	Turner.
Crawford No. 2	Wm. Pintz	Centerpoint.
Eureka No. 4	Jas. Quigley	Carbon.

DAVIESS COUNTY.

Mine.	Mine Boss	Address.
Cabel No. 4	A. Kocher	Washington.
Cabel No. 5	A. Kocher	Washington.
Wilson's No. 4	J. Teverbaugh	Washington.
Mutual	D. W. Davis	Cannelburg.
Hoosier	Grant Stoy	Raglesville.
Union	A. W. Stuckey	Raglesville.
Stuffles No. 3	W. A. Jacobs	Raglesville.
Hawkins	Simon Grill	Washington.
Montgomery No. 2	Thos. Small	Montgomery.
Montgomery No. 3	Thos. Small	Montgomery.
Black Diamond	Henry Osha	Washington.

FOUNTAIN COUNTY.

Silverwood No. 4	Wm. Dalrymple	Silverwood.

GIBSON COUNTY.

Oswald	J. C. Anderson	Silverwood.

GREENE COUNTY.

Island No. 1	S. C. Risher	Linton.
Island No. 2	John Eddie	Linton.
Island Valley	Joseph Fennel	Linton.
Fluhart	Jas. Dunn	Linton.
South Linton	Jos. Small	Linton.
Black Creek	M. C. Randal	Linton.
Summit No. 2	Ernest Dugger	Linton.
Templeton	J. A. Templeton	Linton.
Summit	Frank Lockhart	Linton.
Island Valley No. 2	Geo. Epperson	Linton.
Island Valley No. 3	Peter May	Linton.
Hoosier	John Patton	Linton.
Wildcat	Hugh Archbold	Linton.

KNOX COUNTY.

Prospect Hill	W. R. Scott	Vincennes.
Bicknell	R. M. Freeman	Bicknell.
Edwardsport	Chas. Harding	Edwardsport.
Knox	E. G. Hooper	Bicknell.

MARTIN COUNTY.

Tunnel	F. M. Wampler	Indian Springs.

PARKE COUNTY.

MINE.	MINE BOSS.	ADDRESS.
Parke No. 8	George Mitch	Rosedale.
Cox No. 3	Oscar Busler	Coxville.
Mecca No. 1	James Skene	Mecca.
Lucia	F. J. Urbain	Mecca.
Lyford No. 2	A. Winterbottom	Lyford.
Brazil Block No. 12	R. J. Wallace	Diamond.
Standard	Jas. Baxter	Brazil.
Superior No. 2	John Chesterfield, Sr	Brazil.
Superior No. 1	George Myers	Brazil.
McIntosh No. 1	Samuel Holden	Brazil.
McIntosh No. 3	John Chesterfield, Jr	Brazil.
Otter Creek	John Bolin	Carbon.
Crawford No. 1	Henry Schlatter	Carbon.

PERRY COUNTY.

Cannelton	George W. Briggs	Cannelton.
Troy	H. C. Williams	Troy.
Sulphur Springs	Moses Bolen	Cannelton.

PIKE COUNTY.

Wooley	H. T. Brewis	Petersburg.
Blackburn	John R Willey	Petersburg.
Little's	H. Rose	Littles.
Carbon	C. C. Potter	Sophia.
Ayrshire Nos. 3 and 5	W. L. Smith	Ayrshire.
Hartwell	C. C. Roland	Cabel.
Ayrshire No. 4	Bartley Stinson	Ayrshire.
Aberdeen	Andrew Doods	Oakland City.
Alden	John Carey	Winslow.
Jaxon	David Ingle, Jr	Oakland City.

SULLIVAN COUNTY.

Jumbo	G. H. Sargent	Jackson Hill.
Hymera	Sam Campbell	Hymera.
Phenix No. 1	Joseph Peters	Alum Cave.
Phenix No. 3	Alexander Falls	Alum Cave.
Phenix No. 5	Jas. Stewart	Alum Cave.
Star	S. Woolley	Del Carbo.
Shelburn	C. C. Hall	Shelburn.
Caledonia	Henry Butler	Farnsworth.
Bunker Hill	H. W. Sexton	Farnsworth.
Briar Hill	William James	Dugger.
Ingleside	Evan Price	Dugger.
Dugger	Jno. Griffith	Dugger.
White Ash	William Britton	Hymera.
Green Hill	William McCloud	Sullivan.
Sun Flower	E. H. Dugger	Sullivan.
Jackson Hill No. 2	Ed. Stewart	Jackson Hill.

VANDERBURGH COUNTY.

Mine.	Mine Boss.	Address.
Union	P. Schultheig	Evansville.
Diamond	G. Bonenberger	Evansville.
First Avenue	Frank Guenther	Evansville.
Sunnyside	C. H. Batez	Evansville.
Ingleside	Alex Maul	Evansville.
Unity	John Reese	Evansville.

VERMILLION COUNTY.

Buckeye	William Chesterfield	Clinton.
Brouillet's No. 3	Thos. Clemet	Clinton.
Brouillet's No. 4	Jas. McGinnis	Clinton.
Brouillet's No. 5	Stewart Shirkie	Clinton.
Prince	John Mushett	Clinton.
Torrey No. 4	Geo. Davis	Voorhees.
Cayuga	R. M. Irving	Cayuga.
Oak Hill	William Hutchinson	Clinton.
Willow Grove	Stewart Shirkie, Sr	Clinton.

VIGO COUNTY.

Peerless	Geo. Anthony	Fontanet.
Union	Jas. Johnson	Fontanet.
Diamond No. 2	Thos. Gregory	Fontanet.
Grant Nos. 1 and 2	Jeff Ladson	Burnett.
Nickel Plate	Claude Peck	Ehrmandale.
Klondyke	John Bland, Jr	Ehrmandale.
Ray	Geo. West	Seelyville.
Ehrlich	H. B. Ehrlich	Seelyville.
Hector	William Gray	Seelyville.
Parke No. 10	Thos Bingham	Heckland.
Brick Works	Jno. F. Irwin	West Terre Haute.
Broadhurst	W. L. Irwin	West Terre Haute.
Vigo	William Skank	Ehrmandale.
Royal	Fred Eberwine	Seelyville.
Pfalzer	Wm. M. Harkes	Coal Bluff.
Koch	Geo. Koch	Coal Bluff.

WARRICK COUNTY.

Star No. 1	Geo. F. Archibold	Newburg.
Air Line	T. B. Hall	Chandler.
Chandler	Jesse Simmons	Chandler.
Big Vein	William Woolley	Boonville.
Caledonia	E. P. Hargroves	Boonville.
Big Four	Jno. Kelley	Boonville.
Star No. 2	Geo. Archibold	Newburg.
DeForrest	Mark Wilson	DeForrest.

LIST OF MINES.

Table Showing the Names and Addresses of Persons and Corporations Operating Coal Mines in the State of Indiana, During the Year of 1900, with the Names of Mines in Each County.

CLAY COUNTY.

NAMES.	ADDRESSES.	MINES.	REMARKS.
Brazil Block Coal Co	Brazil	Mine No. 1	
Brazil Block Coal Co	Brazil	Gart No. 3	
Brazil Block Coal Co	Brazil	Gart No. 5	
Brazil Block Coal Co	Brazil	Mine No. 8	
Brazil Block Coal Co	Brazil	Mine No 11	
Briar Block Coal Co	Chicago, Ill	Briar Hill	
Chicago & Indiana Coal Co	Terre Haute	Harrison No. 2	
Chicago & Indiana Coal Co	Terre Haute	Harrison No. 3	
Coal Bluff Mining Co	Terre Haute	Pratt	
Crawford Coal Co	Brazil	Mine No. 3	
Crawford Coal Co	Brazil	Mine No 4	
Crawford Coal Co	Brazil	Mine No. 5	
C. Ehrlich Coal Co	Turner	Klondyke	
Eureka Block Coal Co	Terre Haute	Eureka No. 2	
Eureka Block Coal Co	Terre Haute	Eureka No. 3	
Diamond Block Coal Co	Chicago, Ill	Diamond No. 3	
Goucher, McAdoo & Co	Brazil	Monarch	
Jackson Coal and Mining Co	Brazil	Dewey	
Andrews, Peter	Clay City	Markland	
Somers, Joseph	Staunton	San Pedro	Abandoned.
Zeller, McClellan & Co	Brazil	Columbia No. 3	
Zeller, McClellan & Co	Brazil	Columbia No. 4	
Zeller, McClellan & Co	Brazil	Columbia No. 5	
Lancaster Block Coal Co	Terre Haute	Rob Roy	
Brazil Mining Co	Chicago, Ill	Gladstone	
Crawford Coal Co	Brazil	Louise	Abandoned.
Diamond Block Coal Co	Chicago, Ill	Diamond No 5	
Indiana Bituminous Coal Co	Terre Haute	Silverwood No. 3	
Zeller, McClellan & Co	Brazil	Cloverland	
Brazil Block Coal Co	Brazil	Gart No. 11	
Cloverland Coal and Mining Co	Cloverland	Pearl	
Collins Coal Co	Brazil	Gifford	New mine.
Jackson Coal and Mining Co	Brazil	Cornwall	New mine.
Ehrlich, C	Turner	Fortner	New mine.
Eureka Block Coal Co	Terre Haute	Eureka No. 4	New mine.
Coal Bluff Mining Co	Terre Haute	Lawton	New mine.
Coal Bluff Mining Co	Terre Haute	Glen	New mine.

DAVIESS COUNTY.

Cabel & Co	Washington	Mine No. 4	
Cabel & Co	Washington	Mine No. 9	
Daviess County Coal Co	Montgomery	Mine No. 2	
Daviess County Coal Co	Montgomery	Mine No. 3	
Mutual Mining Co	Cannelburg	Mutual	
Raglesville Coal Co	Raglesville	Hoosier	
Stuffles, James	Raglesville	Mine No. 3	Small mine.
Washington Coal Co	Washington	Hawkins	
Washington Coal Co	Washington	Wilson No. 4	Abandoned.
Winklepleck, Jonas	Raglesville	Union	Small mine.
Black Diamond Coal Co	Washington	Black Diamond	New mine.

FOUNTAIN COUNTY.

Names.	Addresses.	Mines.	Remarks.
Indiana Bituminous Coal Co	Terre Haute	Silverwood No. 2	
Silverwood Coal Co	Silverwood	Sturm	Abandoned.

GIBSON COUNTY.

Princeton Coal Co	Princeton	Oswald	

GREENE COUNTY.

Island Coal Co	Indianapolis	Island City No. 1	
Island Coal Co	Indianapolis	Island No. 2	
Island Valley Coal and Mining Co.	Linton	Island Valley	
Linton Coal and Mining Co	Linton	Fluhart	
South Linton Coal Co	Linton	South Linton	
Summit Coal Co	Bloomfield	Summit No. 1	
Summit Coal Co	Bloomfield	Summit No. 2	
Western Indiana Coal Co	Terre Haute	Templeton	
Dickerson Coal Co	Linton	Wild Cat	New mine.
Island Valley Coal and Mining Co.	Linton	Island Valley No. 2	New mine.
Island Valley Coal and Mining Co.	Linton	Island Valley No. 3	New mine.
Black Creek Coal Co	Linton	Black Creek	New mine.
The Hoosier Coal Co	Bloomfield	Hoosier	New mine.

KNOX COUNTY.

Bicknell Coal Co	Bicknell	Bicknell	
Edwardsport Coal Co	Indianapolis	Edwardsport	
Prospect Hill Coal Co	Vincennes	Prospect Hill	
Knox County Coal Co	Bicknell	Knox Coal Mine	New mine.

MARTIN COUNTY.

Wampler, F. M	Indian Springs.	Tunnel	

PARKE COUNTY.

Brazil Block Coal Co	Brazil	Cox No. 3	
Brazil Block Coal Co	Brazil	Brazil Block No. 12	
Brazil Block Coal Co	Brazil	Otter Creek	
Crawford Coal Co	Brazil	Mine No. 1	
I. McIntosh & Co	Brazil	Mine No. 2	
I. McIntosh & Co	Brazil	Mine No. 3	
Otter Creek Coal Co	Brazil	Mecca No. 1	
Parke County Coal Co	Rosedale	Parke No 8	
Rock Run Coal Co	Brazil	Lucia	
Standard Coal Co	Terre Haute	Standard	
Wabash Valley Coal Co	Clinton	Lyford No. 2	
Zeller, McClellan & Co	Brazil	Superior No. 1	
Zeller, McClellan & Co	Brazil	Superior No. 2	

PERRY COUNTY.

American Cannel Coal Co	Cannelton	Cannelton	
Bergenroth Bros	Troy	Troy	
American Cannel Coal Co	Cannelton	Sulphur Springs	

PIKE COUNTY.

Names.	Addresses.	Mines.	Remarks.
Cabel-Kaufman Coal Co	Cabel	Hartwell	
Ingle, D	Oakland City	Ayrshire	
Potter & Johnson	Oakland City	Carbon	
The S. W. Little Coal Co	Evansville	Blackburn	
The S. W. Little Coal Co	Evansville	Little's	
The S. W. Little Coal Co	Evansville	Rodgers	Reopened.
The J. Wooley Coal Co	Evansville	Petersburg	Reopened.
Aberdeen Coal Co	Petersburg	Aberdeen	New mine.
Alden Mining and Mercantile Co	Winslow	Alden	New mine.
Ingle, D	Oakland City	Ayrshire No. 4	New mine.
Ingle, D	Oakland City	Jaxon	New mine.

SULLIVAN COUNTY.

Green Hill Coal Co	Sullivan	Green Hill	
Sexton and Crowder	Farnsworth	Bunker Hill	
Harder-Hater Coal Co	Del Carbo	Star	
Hymera Coal Co	Hymera	Hymera	
Indiana & Chicago Coal Co	Dugger	Dugger	
Jackson Hill Coal and Coke Co	Eagle	Jumbo	
Dugger Co-operative Coal Co	Dugger	Briar Hill	
New Pittsburg Coal and Coke Co	Alum Cave	Phoenix No. 1	
Shelburn Mining Co	Shelburn	Shelburn	
Rainbow Coal and Mining Co	Farnsworth	Caledonia	
Sullivan Coal Co	Sullivan	Sullivan	Small mine
White Ash Coal Co	Hymera	White Ash	
New Pittsburg Coal and Coke Co	Alum Cave	Phoenix No. 3	New mine.
New Pittsburg Coal and Coke Co	Alum Cave	Phoenix No. 5	New mine.

VANDERBURGH COUNTY.

Diamond Coal and Coke Co	Evansville	Diamond	
Evansville Union Mining Co	Evansville	Union	
John Ingle Coal Co	Evansville	Ingleside	
Lozier, H. A	Evansville	First Avenue	
Sunnyside Coal and Coke Co	Evansville	Sunnyside	

VERMILLION COUNTY.

Brouillet's Creek Coal Co	Clinton	Mine No. 3	
Brouillet's Creek Coal Co	Clinton	Mine No. 4	
Brouillet's Creek Coal Co	Clinton	Mine No. 5	New mine.
Keller Coal Co	Clinton	Prince	
McClellan, Sons & Co	Clinton	Buckeye	
Torrey Coal Co	Voorhees	Torrey No. 4	
Cayuga Press Brick Coal Co	Cayuga	Cayuga	
Oak Hill Coal Co	Clinton	Oak Hill	New mine.

VIGO COUNTY.

Names.	Addresses.	Mines.	Remarks
Miller, A. F	Macksville	Miller	Local.
Broadhurst, J. N. & G	Macksville	Broadhurst	Local.
Coal Bluff Mining Co	Terre Haute	Union	
Ehrlich, Julius	Seelyville	Ehrlich	
Grant Coal Mining Co	Burnett	Grant	
Lankford, William	Macksville	Larimer	Local.
Loughner Coal Co	Seelyville	Hector	
Macksville Coal Co	Macksville	Murray	
Nevins Coal Co	Fontanet	Klondike	
Parke County Coal Co	Rosedale	Parke No. 10	
Terre Haute Brick & Pipe Co	Terre Haute	Brick Works	Local.
Vigo County Coal Co	Seelyville	Ray	
Brazil Mining Co	Chicago, Ill	Nickle Plate	
Grant Coal Mining Co	Burnett	Grant No. 2	
Torrey Coal Co	Voorhees	Glen Oak	New mine.
Fanore Coal Co	Terre Haute	Red Bird	New mine.
Pfaelzer Coal Co	Coal Bluff	Chicago	New mine.
Koch, George	Coal Bluff	Koch	New mine.
Seelyville Coal & Mining Co	Seelyville	Royal	New mine.

WARRICK COUNTY.

Archbold, Jno	Evansville	Star Nos. 1 & 2	
Bartley, Patrick	Evansville	Chandler	
Caledonia Coal Co	Boonville	Caledonia	
DeForrest Coal Co	Evansville	DeForrest	
Hall & Lawrence	Chandler	Air Line	
J. Wooley Coal Co	Evansville	Big Vein	
Goslee, J. S	DeForrest	Buckeye	Re-opened.
Big Four Coal Co	Boonville	Big Four	New mine.

MINOR ACCIDENTS REPORTED AT INDIANA MINES, 1900.

Names.	Date.	Occupation.	Character of Injury.	Cause of Accident.	Name of Mine.	County.
William Shelton	Jan. 1	Miner		Falling slate	Eureka	Clay.
John Lemay	Jan. 1	Miner	Body bruised	Falling slate	Columbia No. 4	Clay.
Joseph Trimble	Jan. 4	Miner	Fingers mashed	Falling slate	Brazil Block No. 12	Parke.
Perry Altman	Jan. 6	Miner	Body bruised	Between mine cars	Gart No. 3	Clay.
John McGuin	Jan. 12	Miner	Hip bruised	Caught between R. R. cars	Brazil Block No. 12	Parke.
Silas Thurman	Jan. 16	Miner	Body bruised	Falling slate	Klondyke	Clay.
William Wright	Jan. 19	Miner	Head cut	Falling slate	Brazil Block No. 12	Parke.
George Vansyke	Jan. 19	Miner	Body bruised	Falling slate	Lyford No. 2	Parke.
No name	Jan. 24	Miner	Body bruised	Between mine cars	Freeman	Greene.
Perry Cruthers	Jan. 25	Driver	Foot mashed	Mine car	Peerless	Vigo.
Charles Kemp	Jan. 31	Shooter	Head burned	Flame from shot	Lucia	Parke.
Arthur Thompson	Jan. 31	Shooter	Head burned	Flame from shot	Lucia	Parke.
John Fininger	Feb. 2	Miner	Side injured	Falling slate	Ingleside	Vanderburgh.
John Burk	Feb. 2	Miner	Head cut	Between cars	Hartwell	Pike.
Daniel Chesterfield	Feb. 3	Driver		Falling slate	Parke No. 10	Parke.
John Northerner	Feb. 8	Miner	Body bruised	Falling coal	Cannelton	Perry.
J. L. Glass	Feb. 8	Miner	Back injured	Falling slate	Brazil Block No. 12	Parke.
Eron Bolin	Feb. 9	Miner	Back injured	Machine truck	Crawford No. 3	Clay.
Court McGill	Feb. 13	Machine runner.	Foot hurt	Mine car	Brazil Block No. 12	Parke.
D. H. Williams	Feb. 14	Mine boss	Leg and head bruised	Falling slate	Parke No. 8	Parke.
John Dixon	Feb. 16	Miner	Head bruised	Falling slate	Brazil Block No. 1	Clay.
John Gripe	Feb. 17	Miner	Body bruised	Between mine cars	Klondyke	Clay.
Williard Fishdale	Feb. 19	Driver		By mine cars	Oswald	Gibson.
Charles Wethers	Feb. 20	Miner	Arm injured	Falling coal	Peerless	Vigo.
Charles Creal	Feb. 20	Miner	Arm injured	Between mine cars	Grant No. 1	Vigo.
Vick Vondour	Feb. 22	Driver		Mine car	Peerless	Vigo.
Tom Rose	Feb. 22	Driver	Leg bruised	Between mine cars	Buckeye	Vermillion.
John Moore	Feb. 26	Driver	Body bruised	By mine car	Buckeye	Vermillion.
Oliver Hicks		Miner	Fractured ankle	Falling slate	Diamond	Vigo.
William Neil	March 6	Driver	Hip and back injured	Falling slate	Oswald	Gibson.
James McColough	March 8	Miner	Hip bruised	Windy shot	Crawford No. 4	Clay.
N. Arego	March 8	Miner	Burned internally	Windy shot	Torrey No. 4	Vermillion.
P. Burtin	March 8	Miner	Burned internally	Windy shot	Torrey No. 4	Vermillion.
J. Barlow	March 8	Miner	Burned internally	Windy shot	Torrey No. 4	Vermillion.
D. Killey	March 8	Miner	Burned internally	Windy shot	Torrey No. 4	Vermillion.

Joe Tiersey	March 8	Miner	Hand burned	Mine car	Torrey No. 4	Vermillion.
Ed. Jackson	March 8	Driver	Foot bruised	Mine car	Torrey No. 4	Vermillion.
Charles Lou	March 8	Driver	Thumb hurt	Mine car	Torrey No. 4	Vermillion.
Lue Mitch	March 8	Driver	Hip hurt	Mine car	Torrey No. 4	Vermillion.
Bert Hill	March 8	Driver	Foot bruised	Falling slate	Torrey No. 4	Vermillion.
John Broadhurst	March 10	Miner	Body bruised	Falling slate	Hartwell	Pike.
Mike Scott	March 16	Miner	Back hurt	Falling slate	Brazil Block No. 12	Parke.
John Broadhurst	March 18	Miner	Body bruised	Falling slate	Hartwell	Pike.
John Godfrey	March 20	Miner	Body bruised	Prop fell on him	White Ash	Sullivan.
William Vasil	March 22	Miner	Arm bruised	Falling slate	Brazil Block	Parke.
Curtis Burge	March 23	Loader	Arm injured	Falling slate	Island No. 2	Greene.
Vaughn Cissel	March 23	Miner	Foot injured	Falling slate	Cable No. 9	Daviess.
William Stinson	March 24	Driver			Oswald	Gibson.
Charles Phillips	March 27		Finger mashed	By cage spring	Ingle	Vanderburgh.
Thomas Forenher	March 31	Miner	Head cut	Falling slate	Cannelton	Perry.
Ben Allen		Miner	Slightly hurt	Falling slate	Carbon	Pike.
William Rowe	April 3	Miner			Star No. 1	Warrick.
James Rowe	April 20	Miner	Narcotic poison	Powder smoke	Star No. 1	Warrick.
Val Galinette	April 30	Miner	Head cut	Falling slate	Torrey No. 4	Vermillion.
John Moncere	April 30	Miner		Powder smoke	Torrey No. 4	Vermillion.
John Robinson	May 1	Track man	Hurt slightly	Falling slate	Pratt	Clay.
Henry Sinclare	May 3	Miner	Back hurt	Falling slate	Union	Vigo.
Henry Liemke	May 3	Miner	Shoulder hurt	Falling slate	Union	Vigo.
John Sprouskie	May 3	Miner	Foot mashed	Mine car	Prince	Vermillion.
Wain Von	May 5	Driver	Burned by powder	Mine car	Ingle	Vanderburgh.
William McAnnually	May 7	Miner	Hip hurt	Drilling shot	Hymera	Sullivan.
Ed. Griffeth	No date	Driver	Foot hurt	No cause	Dugger	Sullivan.
John Pattieson	May 15	Miner	Leg bruised	Falling slate	Brazil Block No. 12	Parke.
Dan Donuhue	May 28	Driver	Slight injury	Between cars	Peerless	Vigo.
Elizah Walts	May 31	Machine runner		Falling slate	Big Vein	Warrick.
A. S. McDonnell	June 6	Driver			Cloverland	Clay.
Sam Tipple	June 7	Driver	Body bruised		Cloverland	Clay.
Gis Mullett	June 19	Miner	Body bruised	Falling slate	Grant No. 4	Vigo.
Sant Hutson	June 19	Miner	Body bruised	Falling slate	Grant No. 4	Vigo.
John Crandell	June 19	Miner	Body bruised	Falling coal	Grant No. 4	Vigo.
Eli Hass	June 20	Miner	Scalp wound	Falling coal	Bicknell	Knox.
Curtis Risley	June 20	Track man	Back injured	Falling coal	Brazil Block No. 10	Clay.
Robert Yemn	June 23	Miner	Back injured	Falling coal	Klondyke	Clay.
Charles Stankes	June 26	Driver	Body bruised	Falling coal	Buckeye	Vermillion.
Charles Harding	June 30	Mine boss	Back injured	Falling slate	Edwardsport	Knox.

MINOR ACCIDENTS REPORTED AT INDIANA MINES, 1900—Continued.

Names.	Date.	Occupation.	Character of Injury.	Cause of Accident.	Name of Mine.	County.
Charles Dixon	June 29	Driver	Foot hurt	Mine car	Summit No. 2	Greene.
John Smith	July 3	Miner	Foot hurt	Mine car	Summit No. 2	Greene.
George Crowder	July 6	Miner	Body bruised	Falling coal	Peerless	Vigo.
Joe Cruthers	July 6	Driver	Foot hurt	Falling slate	Silverwood No. 2	Vermillion.
J. V. Linsley	July 6	Miner	Body bruised	Falling slate	Silverwood No. 2	Vermillion.
Bert Clark	July 10	Trapper	Body bruised	Mine car	Phoenix	Sullivan.
Jeff King	July 20	Miner		Mine car	Prince	Vermillion.
George Cullison	July 21	Miner	Body bruised	Falling slate	Grant No. 1	Vigo.
Joe Glado	July 26	Miner	Arm bruised	Mine car	Summit No. 1	Greene.
	July 26	Driver	Ankle bruised	Mine cars	Eureka No. 2	Clay.
Joe Keen	July 27	Driver	Foot hurt	Machine truck	Brazil Block No. 12	Parke.
Mike Petock	July 27	Miner	Leg injured	Falling slate	Brazil Block No. 12	Parke.
Silas McQueen	July 28	Driver	Body bruised	Mine car	Caledonia	Sullivan.
J. Bledsome	July 28	Driver	Body bruised	Falling slate	Eureka No. 3	Clay.
John Tipton	July 28	Driver	Back injured	Falling slate	Brazil Block No. 8	Clay.
John Carbon	July 29	Miner	Body bruised	Falling slate	San Pedro	Clay.
Will Slow		Miner	Body bruised	Falling coal	Peerless	Vigo.
George Robertson	Aug. —		Arm hurt		Hartwell No. 2	Pike.
Robert Kenedy	Aug. 16	Loader	Head cut		Buckeye	Vermillion.
Clark Wright	Aug. 21	Driver	Back bruised	Falling slate	Brazil Block No. 1	Clay.
Robert Rall	Aug. 22	Cager	Bruised shoulder	Falling slate	Star	Sullivan.
George Robertson	Aug. 22	Miner	Head cut	Falling slate	Oswald	Gibson.
Al Froeske		Miner	Ankle injured	Falling slate	Wild cat	Greene.
Ruban Yucan		Miner	Head cut	Falling coal	Pratt	Clay.
Nathan Crothers	Aug. 24	Miner	Foot injured	Falling slate	Silverwood	Fountain.
Elae Burton	Sept. 7	Miner	Nose bruised	Falling slate	Brazil Block No. 1	Clay.
Ed Vetzel	Sept. 14	Miner	Body bruised	Falling slate	Brazil Block No. 1	Clay.
	Sept. 17	Miner	Body bruised	Falling slate	Freeman	Greene.
Kenneth Simpson	Sept. 18	Driver	Neck injured	Cross bar fell on him	Mecca No. 1	Parke.
Justine Dugger	Sept. 29	Driver	Hand bruised	By cars	Dugger	Sullivan.
James Scott	Sept. 29	Driver	Head cut	By cars	Caledonia	Sullivan.
Buck Hernlow	Sept. 29	Driver	Head cut	By cars	Caledonia	Sullivan.
Fred Koch		Trapper	Slightly injured	Between trap door and car	Peerless	Vigo.
William Erwing		Driver	Back injured	Between roof and car	Peerless	Vigo.
Joe Britwell		Driver	Foot sprained		Phoenix No 1	Sullivan.
Emery Archer		Flag boy	Back hurt	Falling slate	Island No. 1	Greene.

Walter Williams		Driver	Leg injured	Between mine cars	Star	Sullivan.
Mike McMahan	Dec. 5	Miner	Bruised hip	Falling slate	Brazil Block No. 8	Clay.
Phillip Cox	Dec. 8	Miner	Arm and foot injured	Falling slate	Briar Hill	Sullivan.
Nat Hagheman	Dec. 9	Miner	Foot hurt	Fell down air shaft	Buckeye	Greene.
Thomas Flocker	Dec 10	Miner	Hip squeezed	Falling slate	Crawford No. 4	Clay.
Richard Jones	Dec. 10	Driver	Slightly hurt	By mine car	Eureka No. 2	Clay.
Felix Osborn	Dec. 12	Driver	Eye bruised	Kicked by mule	Littles	Pike.
Dave Campbell	Dec. 14	Miner	Hand bruised	Falling slate	Brazil Block No. 12	Parke.
John McNewton	Dec. 14	Miner	Finger bruised	Falling coal	Brazil Block No. 12	Parke.
Ezra Stoner	Dec. 15	Miner	Leg bruised and eye cut	Falling slate	Carbon	Pike.
Henry Dinharp	Dec. 17	Loader	Foot hurt	Between cars	Crawford No. 5	Clay.
Thomas Carter	Dec. 22	Miner	Hand hurt	Falling slate	Crawford No. 5	Clay.
Joe Deedley	Dec. 29	Miner		Falling slate	Jackson Hill No. 1	Sullivan.
		Driver		Kicked by mule	Littles	Pike.
H. Perkens		Loader	Finger nail cut off	Caught between cars	Brazil Block No. 1	Clay.
William Unverferth		Loader	Slightly squeezed	Caught between cars	Wild cat	Greene.
Dan Garlen		Miner	Head hurt		Caledonia	Sullivan.

SERIOUS ACCIDENTS REPORTED AT INDIANA MINES, 1900.

Names.	Date.	Occupation.	Character of Injury.	Cause of Accident.	Name of Mine.	County.
Ralph Thomas	Jan. 5	Miner	Eye injured	Falling coal	Louise	Clay.
W. E Smith	Jan. 30	Miner	Leg broken	Falling slate	Bunker Hill	Sullivan.
William Shields	Jan. 1	Miner	Leg broken	Flying coal from shot	Superior No. 1	Parke.
George Eddy	Feb. 7	Driver	Leg broken	Caught between cars	Buckeye	Vermillion.
William Carlisle	Feb. 7	Driver	Hip broken	Between mine cars	Buckeye	Vermillion.
J. H. Gibson	Feb. 16	Miner	Leg broken	Falling slate	Jackson Hill	Sullivan.
William Fishdale	Feb. 19	Driver	Foot mashed	Between cars	Oswald	Gibson.
George Chesterfield	March 8	Miner	Burned internally	Windy shot	Torrey No. 4	Vermillion.
John Matsie	March 10	Miner	Body badly bruised	Falling coal	Superior No. 2	Parke.
Andrew Malo	March 14	Miner	Both legs broken	Falling coal	Brazil Block No. 11	Clay.
Urlish Schlater	March 1	Miner	Collar bone and rib broke	Falling coal	Crawford No. 1	Parke.
Oliver Hicks	March 1	Driver	Fractured ankle	Falling coal	Torrey No. 4	Vermillion.
Henry Lawhead	April 20	Miner	Injured internally	Falling slate	Star No. 1	Warrick.
Hugh Burris	April 23	Machine runner	Finger cut off	Machine truck	Brazil Block No. 12	Parke.
Charles Veach	April 1	Driver	Jaw fractured	Kicked by mule	Star	Sullivan.

SERIOUS ACCIDENTS REPORTED AT INDIANA MINES, 1900—Continued.

Names.	Date.	Occupation.	Character of Injury.	Cause of Accident.	Name of Mine.	County.
W. T. Evans	May 8	Miner	Collar bone broken	Falling coal	Peerless	Vigo.
John Grim	May 16	Driver	Leg broken	Mine cars	Peerless	Vigo.
Pat Burk	May 23	Miner	Collar bone broken	Falling slate	Peerless	Vigo.
Dan Donahue	May 28	Driver	Leg bruised	Between cars		
Sam Silvers	June 13	Driver	Body bruised	Falling slate	Island No. 2	Greene.
George Webster	June 15	Timberman	Rib broken	Falling timber	Pfaelzer	Vigo.
John Haughie	July 11				Cox No. 3	Parke.
George Little		Miner	Finger mashed off	Falling coal	Phoenix No. 2	Sullivan.
John Newlin		Sinker	Body bruised	Fell in shaft	Klondyke	Clay.
William Hines	Sept. 7	Miner	Leg and two ribs broken	Windy shot	Prince	Vermillion.
Louis Moore	Sept. 18	Miner	Hip and back injured	Falling slate	Nickle Plate	Vigo.
Erwin Yemn	Sept. 23	Miner	Back hurt	Falling slate	Mecca No. 1	Parke.
H. A. Butler	Oct. 3	Mine boss	Hand mashed badly	Falling slate	Caledonia	Warrick.
Shoptal and son	Oct. 9	Miner	Lost one eye	Delayed shot	Island Valley No. 3	Greene.
	Oct. 9	Miner	Body bruised	Delayed shot	Island Valley No. 3	Greene.
Thomas Bell	Oct. 16	Miner	Rib broken	Draw slate	Buckeye	Vermillion.
Robert Blur	Oct. 20	Miner	Head and arm injured	Flying coal		
Charles Mills	Dec. 7	Miner	Foot mashed	Falling slate	Otter Creek No. 1	Parke.
Joe Usrey		Miner	Leg broken	Roof fall	Island Valley	Greene.
Toney Nusell	Oct. 22		Finger mashed off by car	Mine car	Brazil Block No. 10	Clay.
George Weeding			Collar bone broken		Montgomery No. 3	Daviess.
James Newby	July 23	Driver	Leg broken		Peerless	Vigo.
Charles Roby	Oct 12	Miner	Not given	Falling slate	Montgomery No. 3	Daviess.
Richard Huff	No date	Driver	Not given	Mine car and trap door	Caledonia	Sullivan.
John James and Ed Grace	Oct. 23	Miners	Slightly burned	Went back on shot	Buckeye	Vermillion.
Ed Griffiths	No date	Driver	Foot hurt	Not given	Dugger	Sullivan.
Arch Kirkman	No date	Driver	Foot hurt	Not given	Dugger	Sullivan.
William Green	Nov. 19	Miner	Not given	Falling slate	South Linton	Greene.
Sam Silverton	No date	Miner	Back bruised	Falling draw slate	Mecca No. 1	Parke.
Shade Sanderson	Nov. 16	Miner	Not given	Rope broke, fell in shaft with cage	Fanore	Vigo.
Otto Smith	Nov. 16	Miner	Not given	Rope broke, fell in shaft with cage	Fanore	Vigo.
Alonso Baker	Nov. 16	Miner	Not given	Rope broke, fell in shaft with cage	Fanore	Vigo.
James Vanhorn	No date	Driver	Collar bone broken	Mine cars	Buckeye	Vermillion.
John Poleayereio	Nov 16	Miner	Back injured	Falling slate	Klondyke	Vigo.

William Davis	Nov. 15	Miner	Leg broken	Falling slate	Peerless	Vigo.
Charles Dutton	No date	Driver	Finger crushed	Coal falling down shaft	Prince	Vermillion.
Joseph Bloodsoe	No date	Miner	Not given	Got down in powder smoke	Columbia No 4	Clay.

FATAL ACCIDENTS REPORTED AT INDIANA MINES, 1900.

Names.	Date.	Occupation.	Cause of Accident.	Name of Mine.	County.
William Adamson	Jan. 3	Miner	Climbed over gate, fell in shaft	Torrey No. 4	Vermillion.
William Buck	Jan. 5	Cager	Falling slate	Summit No. 2	Greene.
William Hutchinson	Jan. 6	Miner	Falling slate	Dugger	Sullivan.
David Burton	March 5	Miner	Shot blowing through pillar	Brouillet's Creek No. 3	Vermillion.
Celestine Vanderbeck	March 8	Miner	Delayed shot	Cabel No. 9	Daviess.
Harry A. McCord	March 8	Miner	Falling slate	Ayrshire No. 3	Pike.
John Mattsie	March 10	Miner	Falling slate	Superior No. 2	Parke.
Charles Gleson	March 16	Driver	Found between mule and water box	Montgomery No. 3	Daviess.
Hugh Dempsey	May 2	Slate cleaner	Falling slate. Died May 7	Summit No. 2	Greene.
John Tomey	July 17	Loader	Falling slate } Both killed at same time.	Jackson Hill No. 1	Sullivan.
Francis Shanks	July 17	Loader	Falling slate } Both killed at same time.	Jackson Hill No. 1	Sullivan.
James Duncan	July 19	Miner	Falling slate	Ayrshire No. 3	Pike.
Joseph Coker	Oct. 3	Miner	Falling slate	Shelburn	Sullivan.
George Snyder	Oct. 7	Miner	Tamping shot and spark from sulphur fired powder	Caledonia	Warrick.
D. J. Evans	Oct. 26	Mine boss	Descending cage	Diamond No. 5	Clay.
James Wiltie	Nov. 9	Miner	Falling slate	Glen Oak	Vigo.
Alexander Murdock	Nov. 13	Engineer	Fell down shaft	Brazil Block No. 9	Clay.
Vardy Wills	Sept. 12	Loader	Injured by falling slate. Died Sept. 19	Summit No. 2	Greene.

NOTE 1.—On March 31st John Walker, a miner, was found dead in his working place in the Union mine at Evansville. The Coroner's verdict gave heart failure as the cause.

NOTE 2.—Henry Mallen, slack boy employed at the Silverwood No. 3 mine in Clay county, was killed by railroad cars.

CHANGES IN OWNERSHIP OF MINES.

The Green Hill Mine in Sullivan County changed hands in September of last year, and is now owned by Ohio capitalists. It is still, however, operated under the old company name of the Green Hill Coal Company.

D. P. Whitset and his nephew, Paul Whitset, who are connected with the Rainbow Coal and Mining Company, bought the controlling interest in the George Ingle Coal Mine in Sullivan County in November, 1900.

The Nevins Coal Company, whose mine, called Klondike, is located near Grant in Vigo County, sold out this mine to the Brouillet's Creek Coal Company in December, 1900.

The Jaxon Mine in Pike County was purchased last June by David Ingle from William Jackson, its former proprietor.

The Lyford No. 2 Mine in Parke County changed hands in March, 1900, passing into the possession of William Eichberg and his son. It is operated under the name of the Wabash Coal Company as formerly. This mine has changed hands several times in the last few years, and has been allowed to get in bad condition. However, its present owners have expended a large amount of money in improving it, and it is now in first-class condition and is a very desirable piece of coal property. The present owners are also cleaning up the old Lyford No. 1 Mine which burned in 1896, and intend to re-equip it, which, when put in operation, will place this company among the largest producers in the State. These improvements are largely due to the energy and enterprise of the son, William Eichberg, Jr.

The Unity Mine in Vanderburgh County has been operated on a small scale for four or five years, but has passed under the control of the Crescent Coal and Mining Company of Evansville.

OPINION OF ATTORNEY-GENERAL WITH REFERENCE TO PERSONS SERVING AS NIGHT WATCHMEN WITHOUT HAVING HOISTING ENGINEERS' CERTIFICATES; AND ALSO ON MATTER OF SECOND OUTLET OR MAN-WAY.

There have been several complaints made to this office by hoisting engineers during the past year, on account of persons serving as night watchmen who were not holders of hoisting engineers' certificates. The same complaint was made to Mr. Fisher during his term

of office, and he established a precedent by refusing to prosecute such persons, and gave in his report for 1897 his reasons for such action. I decided to refer the matter to the Attorney-General and ask his opinion on the matter.

The question also came up during the year as to whether a mine working a clay and a coal seam both from the same opening, yet working less than ten men in either seam, would be considered as a coal mine subject to the mining laws or not. This question I also submitted to the Attorney-General, and I herewith submit his opinion in both instances:

First. The act of 1897 provides that no person shall serve in the capacity of mine boss, fire boss or hoisting engineer of any coal mine in this State without first having received from the Inspector of Mines a certificate of service or of competency. Section 2 defines the requirements for certificates of service. Section 3 defines the requirements for certificates of competency. Section 5 makes it unlawful for any owner or operator of a coal mine to employ any person in the capacity of mine or fire boss, or hoisting engineer unless such person has a certificate either of service or of competency.

The Inspector of Mines is the sole judge of the competency of applicants. He may determine this by written or oral examination, or both combined, as he may prescribe. Such applicant must show that he is qualified by experience and technical knowledge to perform the duties of mine boss, fire boss, or hoisting engineer. The technical knowledge has reference to the duties to be performed as a mine or fire boss or hoisting engineer. As Inspector of Mines you are the sole judge in determining the issuance of such certificates. It becomes a question of fact with you. Any one who acts as a hoisting engineer must have a certificate. As to what is a hoisting engineer is a matter of fact to be determined by you. You are not limited as to the time of holding the examinations. The places of such examination are fixed by law and you are to determine from time to time, by such examination, who shall hold certificates.

Second. As to your second question: Section 1 of the act of 1879 defines the term "mine" as follows: "The term 'mine' as used in this act includes every shaft, slope or drift which is used or has been used in the mining and removal of coal from and below the surface of the ground."

If one vein of coal is found below another and both are mined out of the same shaft or slope, the number of men employed in the two veins would be counted as one mine and should be added together, because both are mining coal.

The case you put, however, is where there is clay dug and taken out of the same shaft with the coal, the coal being much deeper than the clay, less than ten men being worked in the coal mine and less than ten in the clay.

Many dangers are incident to a coal mine that are entirely wholly absent from a clay pit or mine. In fact the statute does not refer at

all to mining clay. It is my view that the law does not intend that the number of men in the coal mine shall be added to those working on the clay so as to bring the number up to 10. If, however, the number who are working in the clay should become so numerous as to hazard the men in the mine, you would undoubtedly have the right to forbid the use of the same shaft for both purposes.

I have the honor to be Very truly yours,

WM. L. TAYLOR,

Attorney-General.

REPORT OF STATE SUPERVISOR OF OIL INSPECTION.

INDIANAPOLIS, IND., January 14, 1901.

Prof. W. S. Blatchley, State Geologist:

Dear Sir—I have the honor to submit herewith the following report for the year 1900, which is made in compliance with Section 5154 R. S. 1881. The total inspection of petroleum oil for illuminating purposes amounted to 296,800 barrels. Of this number 296,135 barrels were approved for use in the State and 665 barrels were rejected for illuminating purposes.

There are at this time 116 cities and towns of the State in which are located storage tanks for handling refined oils, 14 new stations having been erected during the past year.

There have been no accidents reported resulting from the use of coal oil as an illuminant.

Respectfully submitted,

W. C. ZARING.

DEPUTY STATE SUPERVISORS OF OIL INSPECTION.

Andress, E. H	Lafayette, Ind.
Bell, T. E.	Hammond, Ind.
Blatchley, F. H.	Bainbridge, Ind.
Boltz, J. H.	Winchester, Ind.
Bowman, M. J	Madison, Ind.
Cooper, W. V.	Evansville, Ind.
Crabbs, O. W.	Muncie, Ind.
Davenport, J. B	Elkhart, Ind.
Derr, Walter	South Bend, Ind.
Dorsey, Charles B.	New Albany, Ind.
Dorsey, W. C.	Terre Haute, Ind.
Johnston, J. M	Logansport, Ind.
Lane, C. R	Ft. Wayne, Ind.
Lockwood, C. W	Peru, Ind.
Markley, G. W.	Crawfordsville, Ind.
Schutt, M. A	Michigan City, Ind.
Weems, R. F.	Vincennes, Ind.
Zehrung, P. H	Cambridge City, Ind.

TABLE SHOWING THE TOTAL NUMBER OF BARRELS OF PETROLEUM OIL INSPECTED AT EACH STATION FOR THE YEAR 1900.

Station.	*Bbls.*
Anderson	1,645
Angola	2,166
Argos	371
Attica	2,161
Auburn	1,379
Aurora	2,569
Batesville	1,324
Bedford	2,100
Bloomfield	1,777
Bloomington	1,329
Bluffton	2,094
Boonville	818
Bourbon	1,028
Brazil	3,375
Bremen	281
Brooks	305
Brookville	1,746
Butler	520
Brownstown	454
Churubusco	493
Cincinnati, O.	4,195
Cleveland, O.	8,274
Columbia City	1,419
Columbus	2,833
Connersville	2,324
Corydon	951
Crawfordsville	4,076
Crown Point	1,129
Danville	1,871
Danville, Ill.	223
Decatur	1,450
Delphi	1,480
Elkhart	4,036
Elwood	1,206
Evansville	17,022
Ft. Wayne	10,171
Fowler	1,783
Frankfort	2,702
Franklin	1,925
Francesville	244
Garrett	641
Goshen	2,035
Greencastle	1,385
Greenfield	1,119
Greensburg	1,499
Hammond	3,688

Station.	*Bbls.*
Hartford City	979
Hobart	928
Huntingburg	1,235
Huntington	3,027
Indianapolis	43,860
Jeffersonville	3,094
Jasper	121
Kendallville	1,787
Knox	525
Kokomo	2,626
Lafayette	8,273
Lagrange	1,045
Laporte	2,033
Lebanon	2,752
Liberty	763
Ligonier	1,060
Lima, O.	729
Logansport	4,101
Louisville, Ky.	3,180
Madison	3,383
Mansfield	1,886
Marion	2,086
Martinsville	1,094
Michigan City	2,218
Monticello	476
Monroeville	364
Mount Vernon	718
Muncie	1,668
Nappanee	1,304
New Albany	3,806
New Castle	1,648
Newport	840
North Manchester	1,348
North Vernon	1,380
Oakland City	548
Paoli	833
Peru	2,617
Petersburg	278
Pierceton	525
Plainfield	380
Plymouth	1,134
Porter	565
Portland	1,798
Poseyville	937
Princeton	1,803
Remington	829
Rensselaer	1,002
Richmond	4,815
Roachdale	341
Rochester	1,509

Station.	*Bbls.*
Rockport	904
Rockville	1,796
Rushville	1,813
Salem	1,170
Scottsburg	764
Seymour	1,919
Shelbyville	2,387
South Bend	8,032
Spencer	706
St. Joe	254
Sullivan	1,727
Tell City	920
Terre Haute	11,137
Tipton	511
Toledo, O.	1,800
Topeka	196
Union City	2,328
Valparaiso	1,739
Veedersburg	1,226
Vevay	129
Vincennes	5,973
Wabash	2,163
Walkerton	1,059
Warsaw	1,609
Washington	3,221
Westfield	1,420
Whiting	5,000
Winamac	1,030
Total	296,800

TABLE SHOWING NUMBER OF BARRELS OF MINERS' OIL INSPECTED FOR THE YEAR 1900.

Where Inspected.	*Bbls.*
Brazil	392
Bernard	5
Clinton	11
Dugger	3
Evansville	154
Farnsworth	2
Fontanet	25
Heckland	14
Indianapolis	179
Lyford	7
Rosedale	1
Shelburn	1
Staunton	2
Turner	1
Terre Haute	656
Vincennes	169
Total	1,622

THE PETROLEUM INDUSTRY IN INDIANA IN 1900.

By W. S. Blatchley.

TRENTON ROCK PETROLEUM.

The Trenton limestone, which underlies the whole of the State of Indiana, is the source of by far the greater part of the gas and oil produced in the State. The Trenton is one of the lower or older formations of the Lower Silurian System. The upper formation of this system, namely the Hudson River limestones and shales, forms the surface rocks of several counties in the southeastern part of the State. Between the Hudson River limestone and the Trenton limestone is a persistent, fine-grained dark brown or blackish shale, known as the Utica shale. This lies immediately on top of the Trenton limestone and forms the necessary impervious cover over the porous portions of that formation. In these porous portions the oil and gas are stored, and the presence of the overlying close grained Utica shale has, for centuries, kept these stored products from escaping upward, and passing off as volatile products. Trenton limestone does not outcrop or form the surface in any part of the State, and its known closest proximity to the surface is near Lawrenceburg, Dearborn County, where it is 348 feet below.

Formation of Porous Portions of Trenton Limestone.—The Trenton limestone is a sedimentary rock; i. e., one which was laid down in water—the bottom of the sea—ages ago. When first formed it was a nearly pure calcium carbonate or carbonate of lime. In the course of time, certain areas of the sea bottom, covered with the incipient limestone, were slowly raised until they became higher than the others, and formed shallow basins, lagoons or bays. Some of these raised portions covered very large areas. Others were isolated or separated from the main area, sometimes by a distance of 20 to 30 miles. The outline of all was irregular, with many indentations along the margins. In these more shallow portions of the Silurian seas the water became in time very briny and caused a chemical change in the rock. To the lime carbonate was added some magnesia from the brine, and a magnesia-lime carbonate called "dolomite"

resulted. Wherever this change took place—which was only in the shallow, briny areas noted—the resulting *dolomite* was porous. This porous condition was due to the fact that the new crystals of dolomite were smaller than, and never entirely filled the spaces occupied by, the older crystals of lime carbonate. *The larger areas of the Trenton limestone deposit beneath the present bounds of Indiana were either too impure to admit of a change into dolomite, or the conditions of sea level were never such that the change could take place; hence they are non-porous and barren of either oil or gas.*

ORIGIN OF PETROLEUM.—The petroleum of the Trenton limestone was formed in that rock many thousands of years ago. Myriads of animals, as polyps, bryozoans, crinoids, brachiopods, trilobites and fishes, existed in the sea at the time the sediment of the Trenton limestone was being deposited. The presence of such swarms of animal life made necessary the existence of an abundance of plants, since the plant must ever precede the animal and gather for the latter the energy, and form for it the food—the living protoplasm—necessary to its existence. These plants were mostly marine algæ or seaweeds and fucoids, though doubtless many other forms existed of which no remains have been preserved in the rocks of that age. As these organisms, both plant and animal, died, their bodies, in vast numbers, were buried in the slowly forming sediment. By the waters above and the ooze around them they were shut off from the free oxygen of the air and the decay ordinarily undergone by dead organisms was thereby prevented. Instead of decaying, their soft parts underwent a *process of slow destructive distillation* which resulted in the petroleum now being brought up from the rocky depths where it has long been stored. The crusts and shells of their bodies went far toward forming the carbonate of lime of the Trenton rock, fully 80 per cent. of which is derived from the remains of their secretions and incrustations. It is a well known fact that if wood, coal or the body of any animal be placed in an air-tight retort and heated, a distillation will occur, and the object will be changed to gaseous, oily and solid matters. In the absence of heat and air a very long period of time will bring about the same results. By this is meant the process of "slow destructive distillation" above mentioned.

ANTICLINES AND SYNCLINES.—The surface of the Trenton limestone is not level as many people suppose, but, like the surface of the earth, is a series of alternating arches and depressions or ridges and valleys. The arches or domes are like inverted troughs and vary much in width and area, as do also the depressions between them. Wherever gas and oil occur they will be found in a porous stratum in

one of the arches, or *anticlines*, as they are called. If a bore happens to be put down and strikes a depression or *syncline* between the arches, salt water will invariably be found. If both gas and oil are present in a certain area, and the bore strikes the flank or side of the arch, oil will result. If the bore strikes the crest or dome of the arch, gas will flow. The cause of this is simple, being due to the arrangement of the three fluids according to their relative weights. When the oil was first formed it was pushed or carried hither and thither by the heavier salt water behind it. Much of it was carried away by the water and lost, but wherever one of the porous areas existed in the side or top of an anticline the oil was carried into it and there remained. During the ages which have elapsed much of the oil was changed into a volatile gas, which rose into the higher porous portions of the anticlines or ridges of the Trenton limestone. As this gas accumulated, it pressed back the remaining oil into the sides or flanks of the arch. The oil being lighter than the water, rested upon the latter and prevented it from rising into the higher porous portions of the limestone. When a bore is put down and strikes gas the latter will flow until the quantity which is stored in the porous area of the anticline is exhausted, when the oil, if any be present on the flanks or lower portions of the porous stratum, will rise in the gas well. It may be that the oil has been carried by the salt water into the porous portions of another anticline, and that only salt water occurs beneath the gas. If this be true, the water will fill the porous reservoir as soon as the gas is exhausted. The anticlines vary much in size, their domes running from scores of miles down to a half mile or less in width. The gas in the higher part of each anticline is, therefore, often shut off from that in a neighboring anticline by the intervening oil or water, or both. In the same way the oil in an anticline which contains oil only may be shut off from that in another anticline by the salt water filling all the porous portions of the syncline between. It often happens that a gas bore is put down which strikes the crest of a narrow anticline or raised portion of Trenton limestone which has not before been pierced. As a result the so-called rock pressure of the gas is at first high, but rapidly declines on account of the small size of the anticline. All the wider and higher anticlines in the main gas field in Indiana in which porous Trenton occurs, have been pierced many times, and the stored gaseous product has become almost exhausted.

Origin of Natural Gas.—From what has been said it will be seen that both natural gas and oil have a common origin; viz., the destructive distillation, carried on through thousands of years, of

the plants and animals which existed in the Trenton Period. The gas is only the lighter and volatile portion of the oil, which has risen into the higher interstices of the limestone. If an open barrel be filled with crude petroleum from the Trenton limestone of Indiana and exposed for a single summer to the air, more than half of the contents will pass away in the form of vapor, and a sticky, tar-like residue will remain. If by some means the escaping vapor could be collected and analyzed it would be found in the main to have the same composition as natural gas. In fact it would be natural gas and would burn as freely as a sample of that valuable fuel, collected in the ordinary way. In the depths of the rock the evaporation of the oil has been extremely slow and the amount has been limited both by the varying pressure of the overlying gas and the underlying water. There is little doubt, however, but that all the natural gas of the Trenton limestone has been so derived. The amount of gas and oil accumulated in any field will depend almost wholly upon the area and height of the anticline, and upon the relative thickness and degree of porosity of the dolomitic portion of the Trenton limestone.

POOLS NOT NECESSARILY CONNECTED.—A fallacy which is held by many would-be operators in the Indiana field is, that oil fields or pools run in lines, and that one field is connected with all others, the oil flowing from one to the other, through a continuous strip of porous rock. This may in part be true in the Pennsylvania oil regions, but it is wholly untrue in the Trenton limestone area of Ohio and Indiana. While all the so-called "pools" of that area are found in the anticlines in the Trenton formation, they are not necessarily connected, nor do the anticlines run in straight lines. From what has been said about the origin of the porous areas of the Trenton limestone it will be seen that a pool may be of any shape, and may lie in any direction from any other pool. Its boundaries may be straight or sinuous; its area one square yard or one thousand square miles. If the conditions necessary for the storing of petroleum, namely, a porous reservoir, located in the flank or dome of an anticline of the Trenton limestone, with an impervious cover above it and a water pressure below it, have been present in the past, the oil will very likely be found, whatever the shape, size or relative location as to other similar reservoirs. If any one of these conditions is lacking or has been lacking, the bore is sure to be a dry hole. Inasmuch as the top of the Trenton limestone in the main Indiana field is everywhere from 700 to 1,000 feet below the surface, it will be seen

that the problem of locating in advance a paying well is a most difficult one.

No Surface Indications of Oil.—Samples of oil or of water containing oil are constantly being received at the office of the State Geologist from stations outside of the present producing oil field. For the most part they have been gathered near the surface, and the persons collecting them believe that they are "surface indications" of a large supply of the precious liquid. In this they are mistaken, for the sample collected, if traced to its source, will be found to have exuded from a crevice in some neighboring stratum of rock, or to have come from some large mass of vegetable matter, partially or wholly covered with water or mud. Every shale, sandstone or limestone in the State contains oil in greater or less quantities, and even where the amount is infinitesimally small, enough may collect to exude from a crevice and produce a showing upon some near-by surface of water. In the minutely diffused state in which the oil is originally formed it is wholly without value. Like all other forms of mineral wealth, it must be concentrated into reservoirs, the so-called "pools" of the oil fields, before it can be utilized by man.

Again, many letters are received, asking: "What are the surface indications of gas or oil?" To all such inquiries I reply that in Indiana there is absolutely no such thing as a "surface indication" of either of these fuels. Where they occur in paying quantities in this State, they are found at depths varying from 700 to 1,500 feet below the surface, and no human being can say with certainty that a bore put down, even in the best prospective territory, will yield either in paying quantities. The operator who is thinking of putting down a bore in undeveloped territory, can only sink his drill; he has no way of knowing beforehand what the result will be. He may pierce the center of a reservoir and get a 500 barrel well; he may strike near its outer rim and get a 10 barrel well—he may miss it altogether and get a dry hole. One thing he can rely upon if he strikes a productive well, and that is, that he is drawing upon a stored product which is not now being formed in the rock from which it is drawn, and that, therefore, he must eventually exhaust the stock from the immediate vicinity of his bore.

Necessity of Accurate Surface Levels.—Where a bore for petroleum has resulted in a good producing well, the level of the surface of the Trenton rock below tide should be carefully ascertained. This can be done only by running a transit level from the nearest point where the surface level is known, usually on a railway, to the surface of the bore. By subtracting the surface level of the

bore from the depth at which Trenton limestone is first struck, the surface level of the latter will be obtained. In but few places in the State is Trenton found above sea level. Where so found the depth to Trenton will be less than the surface level of the bore, and should be subtracted accordingly.

The location of the first dozen or more wells in any area a mile or two square must of necessity be largely a matter of guess work, but if the surface level of the Trenton in each bore, productive or dry, be carefully ascertained, the trend of the anticline and the approximate limits of the field or pool can be soon determined. Too much guess work concerning the surface level of the spot on which the well is located has been done in the past. In a broken country it is difficult for any man to guess approximately at the relative levels of two points a quarter of a mile apart, and the new level should always be ascertained with instruments. Of course the surface level of the bore has nothing to do with the absolute height or surface level of the Trenton, or the absence or presence of the petroleum, but it has a great deal to do with the *accurate determination* of the surface level of the Trenton, and therefore with the location of future wells. If a few thousand dollars had been spent in Indiana in past days in the careful determination of surface levels, it would have saved a few hundred thousand which have been sunk in dry holes.

Topography of the Main Indiana Oil Field.—The surface of the main area now yielding Trenton Rock oil in Indiana was originally one great plain, with only occasional small undulations to break its monotony. This plain has been eroded in many places by the streams, which in the past have been much larger than at present. Wherever bluffs or hills are found they are but the results of such erosion. But few outcrops of rock occur within the oil field, and they are found only along the streams where the water has eroded deep channels through the drift and bowlder clay, everywhere covering the oil territory to a depth of from 50 to 250 feet. These outcrops belong to the Niagara group of the Upper Silurian Period.

The formations passed through by the drill in all parts of the field before the Trenton limestone is reached are, therefore, as follows: Drift; Niagara limestone; Hudson River limestone; Utica shale. In the eastern half of the field an average section showing the thickness of each formation passed through would be about as follows;

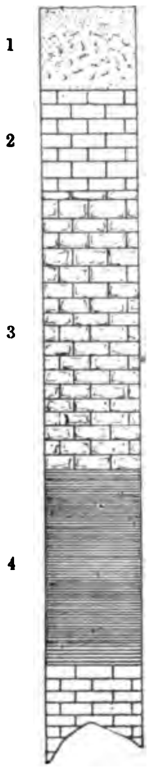


Fig. 73.

1. Drift .... 125 feet.
2. Niagara limestone ...... 150 feet.
3. Hudson River limestone.. 425 feet.
4. Utica shale .... 300 feet.

In the western portion of the field the average bore shows:

1. Drift .... 175 feet.
2. Niagara limestone ...... 225 feet.
3. Hudson River limestone.. 380 feet.
4. Utica shale .... 200 feet.

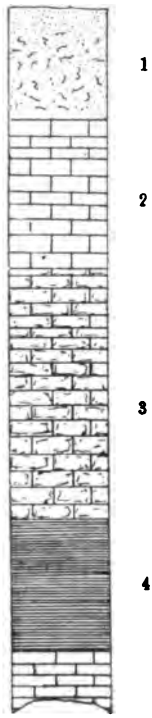


Fig. 74.

Throughout the Indiana field an eight or ten-inch drive pipe is forced down through the drift to the Niagara limestone. The salt water usually found in the Niagara is cased off by an iron tube $5\frac{5}{8}$ or $6\frac{1}{4}$ inches in diameter, which reaches to the soft blue Hudson River limestone underlying the Niagara. This second limestone and the Utica shale beneath it contain no water. The Trenton is everywhere overlain with the soft, dark colored Utica shale which forms an impervious cover through which neither gas nor oil can escape. From the bottom of this shale the drill passes at once into the hard crust of the Trenton limestone. Two "pay streaks" or porous layers are usually found in the Trenton, and it is only in them that oil occurs. The first or upper one is usually 15 to 25 feet below the top of the Trenton; the other is 15 to 25 feet below the bottom of the first. While the Trenton rock in Indiana varies in known thickness from 470 to 586 feet the porous portions containing oil are found only in its upper fourth. It has been found useless to drill into the Trenton more than 70 feet, since of the 10,000 and more bores which have been put down in the State, but three or four have found oil or gas below that depth.

Salt Water.—More or less salt water is always found in the Niagara limestone, and is shut off by the casing put down through that formation. Salt water also occurs in the Trenton rock in all portions of the Indiana field. Usually a difference of only six to 10 feet in the elevation or depression of the surface of the Trenton defines oil and salt water territory. If the well has been located

over a syncline, or trough, in the Trenton, salt water is apt to be found before the drilling has proceeded very far into that formation, and a well yielding only salt water usually results. If, however, the bore pierces the dome or flank of an anticline, either gas or oil will be struck, and the operator is usually careful to see that the drilling is stopped before the level of the water producing rock is reached.

It is now almost universally admitted that the rock pressure in any oil field is nothing more or less than water pressure, as in artesian wells, the water entering the porous stratum at some point where the latter outcrops and so forming a head or source. Hence, the deeper the well the greater the head of water and the higher the rock pressure. The porous rock contains a limited amount of oil, held in place by the overlying shale. The salt water is below this oil, ever pressing it upward into the vent furnished by the drill hole. As the supply of oil is gradually lessened, the water rises to fill the pores, and the rock pressure is lowered. The pressure does not tell us anything about the volume or amount of oil stored in the rock; but the rate of diminution of pressure furnishes an excellent index of the rapidity with which that amount is being lessened. When the supply of oil is exhausted, as it naturally will be in time, there is no source from which it can be renewed. The salt water will rise and occupy the space which formerly held the oil and it will come to stay.

In some cases, however, both water and oil are found together in the same stratum. Some of the best wells in the Indiana field are big salt water wells, pumping from 150 to 700, or even more, barrels of salt water, and 40 to 150 barrels of oil daily. It costs much more to operate a well of this kind, as it has to be pumped with a beam, and, therefore, requires a separate power. Such wells are usually longer lived, as the salt water seems to renew the quantity of oil by bringing it in from quite an area of the porous stratum which the bore has pierced. Moreover, the salt water seems to keep the pores of the oil rock free from paraffine and other materials which have a tendency to clog them up, and a well producing four or five barrels of water a day in connection with the oil, is preferred by many operators to one that produces oil alone.

Cost of a Producing Well.—According to careful estimates, the average cost of drilling and fitting up the first productive well on a lease, if drilled to a depth of 1,000 feet, was about as follows in the Indiana field on October 15, 1900:

Rig or derrick	$325
Drilling	475
Drive pipe	90
Casing	100
Shooting	110
Tubing and pumping outfit	180
Engine and boiler	450
Two tanks, at $90	180
Belting and lead lines	125
Total	$2,035

The second well on the same lease will cost about $840 less, as the engine and boiler, tanks and rig can be used for both wells, though there will be a loss of about $125 in tearing down and putting up a new derrick. If natural gas is available and it is so desired, a gas engine, costing from $325 to $450, can be substituted for the boiler and engine. With the advanced methods of pumping by which oscillating pull wheels, rods, etc., are used, 20 or more wells can be connected to one power, and the cost of production be thereby greatly decreased.

Cost of Operating a Lease.—The cost of operating an oil lease after the production has been established need not be more than $75 per month, the salary of the pumper being $50, and the cost of fuel, if gas, about $25. A dozen, or even 20 wells can, however, be operated almost as cheaply as one after they have been connected with the power. An extra pumper may have to be employed, but otherwise no additional expense is entailed.

Where the plant has been established, it will pay to pump as low as two or three wells, even if the yield is only three barrels each per day, provided the price of oil is 70 cents or more per barrel.

The estimate of expense and income from two three-barrel wells, after deducting the royalty of one-sixth, is as follows:

Salary of pumper	$50
Cost of fuel	25
	$75
Income per month:	
150 barrels oil, at 70 cents	$105
Net income per month	$30

With six three-barrel wells on the lease, the income would be $315 and the expense $75; a net gain of $240 per month.

From what has been written it will be seen that the cost of drilling and operating a lease in any of the Indiana Trenton rock fields is as

low or lower than elsewhere in the eastern United States for the following reasons: (a) The wells are comparatively shallow, the Trenton limestone in most instances being struck at less than 1,000 feet. (b) It is seldom that more than 150 feet of drive pipe and 400 feet of casing are necessary. (c) On account of a comparatively level surface a large number of wells can be connected to and pumped with one power. (d) Gas for fuel or for running gas engines is usually plentiful. (e) Transportation facilities are excellent, a system of pipe lines permeating all parts of the main field.

According to some of the leading operators, it costs 50 cents a barrel to produce oil on the average lease in the main Indiana field. Whatever is received above that sum is net profit. If the lease is small the cost is much greater in proportion. Oil at 90 cents brings a good price and a fair profit. When the price rises above the dollar mark, many operators claim that it increases the cost of production in the following ways: The price of supplies is usually made higher; an increase in the wages of drillers and pumpers is likely to be demanded; there is too much competition and too great a scramble for territory; the land owners demand a higher royalty and, in many instances, a large bonus; too much wild-catting is done and the percentage of dry holes is thereby greatly increased; the stock of oil in storage is increased too rapidly. All of these things bring in time a reaction which causes the price to fall too low, and for a year or two many of the operators produce at a loss, or a very small profit.

Whatever the price, the profits will depend largely upon the way the property is managed. Success as an oil operator depends upon the same watchful energy as brings success in any other business. One's pumps should be kept at work steadily so as to get all the oil possible. The drilling tools, lead pipes and pumping machinery should be kept in good repair. In average territory the wells should be put down at intervals of 720x680 feet, which will bring eight wells on each 80-acre tract. In exceptionally good territory, 10 bores can, with profit, be sunk on 80 acres, bringing them 551 feet apart each way. Above all, one should be on the lookout for overflow and leakage. Much of what would otherwise be profit in oil property is allowed to go to waste. Finally, if the property is inside the limits of productive territory, the successful oil man is he who lets other people do the wild-catting, and who follows where they lead.

THE MAIN INDIANA OIL FIELD IN 1900.

No great strikes were made in the main Indiana oil field in 1900, but new developments increased the area of the field so that it now

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extends from the Ohio-Indiana State line westward to Marion, Grant County, and from Warren, Huntington County, south to Hartford City, Blackford County. The greatest length of the field is about 45 miles and its extreme width about 20 miles. There are, however, a large number of sections within the area thus bounded which have not been fully tested. A map showing the exact area tested up to January 1st, 1897, with details of the results of the tests to that date, was published in the Twenty-first (1896) report of this Department. This map, enlarged and modified so as to show the field as it was on January 1, 1901, is published in connection with the present paper.

DEVELOPMENTS IN ADAMS COUNTY IN 1900.—During the year a number of good producing wells were drilled in in Wabash, Blue Creek and Jefferson townships, Adams County. These extended the known productive territory from its eastern limit in sections 29 and 32, Wabash Township, as shown on the map of 1896, to the State line.

In the southwest corner of Blue Creek Township and in the adjoining township of Mercer County, Ohio, is the so-called "Dudgeon Pool," which was first opened in the fall of 1899. A number of new bores were put down in 1900, the best of which were on the Fisher lease. Four of them were large salt water wells, each of which, for a time, brought in 50 barrels and more of oil per day. In December there were about 18 wells producing in sections 22, 27 and 34, Blue Creek Township. Some of them were quite small and the total production of the 18 was about 200 barrels daily. In the southwest quarter of section 29 and the northwest of section 32, several small wells have been drilled by the Superior Oil Company. The top of the Trenton is here found at about 1,075 feet. Some of the wells yield gas enough to run boiler and gas engines.

The best wells of the season in Blue Creek Township were on the Rawley & Tumbleson leases in section 31. They were drilled in in October and December. The No. 2 Rawley on the northeast corner of the southwest quarter of the section was finished October 1st, and flowed natural, without shooting, 210 barrels per day for the first five days, and 180 barrels per day for the next week. It yielded no water and just gas enough to cause it to flow. The record of its bore is as follows:

Drive pipe	114 feet.
Casing	370 feet.
Top of Trenton	1,059 feet.
Total depth	1,108 feet.

The Tumbleson well, a few hundred feet north, was a big salt

water well when first finished, but in about a week began to produce oil, and made 700 barrels in 27 hours. A bore on the Studebaker farm, 600 feet north and 600 east, of the No. 2 Rawley, was a dry hole. This is a good example of the uncertainty of oil operations in Indiana Trenton rock, even in the best productive territory.

North of New Corydon, in sections 19, 29 and 30, and the north half of sections 31 and 32, Jefferson Township, some wells were sunk in 1900 which started in as fine producers, some of them yielding 80 to 100 barrels daily. In a few of them three pay streaks were found, the first between 18 and 25 feet in Trenton; the second between 30 and 35 feet in, and the third between 40 and 50 feet. The top of Trenton is found in this locality at about 1,080 feet. The wells yield quite a quantity of gas and pump but little water. A dry hole was bored in section 21. The north half of the township has not as yet been tested.

A number of good wells were put down in the spring of 1900 just west of Geneva, in the west half of section 29, Wabash Township. Some of them started in at 150 barrels daily. The so-called "loblolly,"* or bed of an old preglacial stream, runs through the center of this section, making necessary 400 feet of drive pipe in some of the bores. The average distance to the top of Trenton is here 987 feet. East of Geneva in section 28 and the west half of section 27, 10 bores had been put down up to November 1st. No dry holes had been found, and the wells were averaging 10 to 12 barrels each per day. In a few of the wells which started at 50 to 60 barrels the pay streaks were very porous and contained much pyrites. In the northwest quarter of section 26, Wabash Township, a bore on the Chrisman farm resulted in much gas and little oil. The top of Trenton was struck at 1,021 feet, while the drift was but 54 feet thick. Some good wells were sunk in the north half of sections 32 and 33, where the "sand" was found at a depth of 989 feet. A small producer in the northeast quarter of section 35 was the only other bore in the south half of the township.

In the north half, in sections 8, 9, 16, 17, 20 and 21, the Main Oil Co. has a tract of 1,300 acres under lease on which seven bores were put down in 1900. The average distance to the top of Trenton was 1,035 feet, and the average initial production about 30 barrels per well. One bore, in the north half of section 21, yielded gas only. The northernmost of the productive wells is about one and one-half miles south of Berne. A dry hole in the northeast quarter of section 11 stopped operations to the eastward in this township.

*For an account of this old channel see 21st Ann. Rep. Dep. Geol. and Nat. Res. of Ind., 1896, p. 65.

There is little doubt but that much of the undrilled territory east of Geneva and within the bounds of the field shown on the map will, in the future, be found productive of oil. When it is fairly opened up, the long sought for gap between the Ohio and Indiana Trenton oil fields will have been filled, and the entire producing area of both States will go down in history as one of the largest and most productive oil fields hitherto known to man.

DEVELOPMENTS IN JAY COUNTY IN 1900.—During 1899 and 1900 all the wells east of the G. R. & I. Railway, in Jay County, in the territory marked light producing on the former map, were abandoned. Some fairly productive wells were sunk in the north half of sections 5 and 6, Bear Creek Township, and a number of good ones were drilled in section 7. This section was, however, already considered good territory.

In the northern half of Jackson Township but few new developments are to be noted. A dozen or more good wells have been drilled in each of sections 11 and 12 since the first map was published. This territory has held up well, the annual loss in production being small. The north half of section 8 has recently proven quite productive and a good well or two has been sunk in the southwest quarter of section 10. The whole of section 15 has been abandoned, the few wells therein not paying for pumping. Three fair producing bores were put down in 1899 and 1900, in the northeast quarter of section 33, the Trenton being struck at about 1,000 feet and the production starting out at an average of 50 barrels. A light producer was also sunk near the center of section 35, but, on account of lack of pipe lines, has not been pumped.

In Greene Township, three bores in the north half of section 8 and two in the southeast quarter of section 17, drilled for gas, produced on an average of two barrels of oil per day until they were capped in. The Trenton was struck at about 940 feet, the thickness of drift being about 90 feet. Good gas wells have been sunk in sections 18, 19 and 20 adjoining section 17; also in the northeast quarter of section 26, southeast quarter of section 28, southwest quarter of section 32 and northwest quarter of section 34.

In Penn Township but few changes are necessary in the old map. Several light wells have been sunk in the southwest quarter of section 3. Some dry holes have been drilled in the northeast quarter of section 21, and oil has drowned out the gas in a number of wells in the east half of section 22 and the north half of section 27. In the latter locality the tubing from wells formerly producing one and one-half million cubic feet of gas daily was pulled out and the bores

sunk deeper, when the wells started out at 160 barrels of oil daily. The famous Gardner pool, in sections 24 and 25 Penn and 19 and 30 Jackson townships,* is still producing large quantities of oil.

A small pool which for a short time created much excitement was opened up by the Davenport Oil Co. on the northwest quarter of section 28, Penn Township, in the first half of 1900. Five wells were drilled, the average record of the bores being as follows:

Drive pipe	196 feet.
Casing	315 feet.
Trenton struck at	945 feet.
Total depth	1,030 feet.

Bore No. 1 started at 180 barrels daily, but on November 1st had fallen to six barrels. No. 2 made 20 barrels a day for 30 days, then fell to three barrels and was abandoned. No. 3 started at 240 barrels and after yielding 30 tanks became dry. Nos. 4 and 5 were dry holes.

The Salamonie Oil Co., in April, 1900, bought the leases on 440 acres adjoining the above pool in sections 28, 29 and 32. Ten wells, making a total of 160 barrels daily, were being operated when the property was bought, the price paid being $40,000. During the year the new company put down three bores. One, a dry gas well, was on the northeast of section 32. In it Trenton was struck at 927 feet. A dry hole was sunk on the northwest quarter of the southwest quarter of section 28; while the third yielded only a small amount of oil. Between April 1st and November 1st, $20,000 worth of oil was produced on the lease and the property on November 1st was yielding 75 barrels daily.

Much of the present gas producing territory in Penn, Knox and Greene townships, Jay County, will in future become productive of oil, and a light producing field will result. Where the Trenton lies 10 to 20 feet lower than in the area at present yielding gas, oil will be found in large quantities. Many of the gas wells can, and doubtless will be drilled deeper, a large output of oil resulting.

DEVELOPMENTS IN WELLS COUNTY IN 1900.—In Nottingham Township, where the first paying wells in the Indiana field were sunk in 1891, numerous bores have in recent years been put down on territory already regarded as "good." The productive territory mapped in 1896 has not been enlarged to any extent, but has held up exceedingly well. The Brookhart farm of 160 acres on section 31, of which especial mention was made in the former report, had, up to January 1, 1900, yielded the owner $18,000 on one-eighth royalty,

* See p. 67, 21st Ann. Rep.

and was still producing about 400 barrels a month. On it 15 wells have been sunk, but one of which has been abandoned. A new bore on the Cory lease in section 27, within 600 feet of the first well, started in May, 1900, at 200 barrels; a bore with an equal initial output was drilled in about the same time on the Scott lease in section 30. In the words of one prominent operator, "Nottingham and Jackson townships, Wells County, have proven the best territory for small operators in the State. They contain a large number of small producing wells which have held out in a remarkable manner."

In Chester Township all of section 5 has developed into fair producing territory, while the north half of section 6 has proven good. Some fair wells have been drilled in the south half of sections 9 and 10. On the M. Quill farm in the southwest of section 10 the record of bore No. 1 was as follows:

Drive pipe	52 feet.
Casing	330 feet.
Top of Trenton	998 feet.
Total depth	1,035 feet.

When started it threw a solid stream of oil 40 feet above the derrick, but soon dropped to a five barrel well. No. 2, 600 feet east, started in at 30 barrels; while a bore finished about the same time 600 feet south on the Kennedy farm, section 15, started at 130 barrels. The north half of section 15 and the northeast quarter of section 16 have produced some other good wells, and may now be classed as good territory. Section 28, undeveloped on the former map, has become a fair producer. A number of wells were put down in other sections of Chester Township in 1900, but their output made no necessary change in the map as formerly presented.

In Liberty Township only sections 28, 31, 32 and 33 in the southwest corner have produced oil in commercial quantity. On the southwest quarter of section 32 the Hunt Oil Co. put down six bores, two of which resulted in a good yield, the other four being light. The average record of these bores was about as follows:

Drive pipe	67 feet.
Casing	390 feet.
Top of Trenton	1,006 feet.
First pay streak	1,015 feet.
Total depth	1,040 feet.

The best of the wells on the Kingan lease started June 28th at 130 barrels, but by October 15th the output had fallen to 30 barrels daily. The top of Trenton in the southeast quarter of the section is

found at about 1,027 feet, and the wells produce much salt water. Bores on the southwest quarter of section 28 and the northwest quarter of section 33 have resulted in a few light producing wells, the initial output running from five to 25 barrels. The south half of section 31 is fair territory but the north half has as yet proven light. It is not likely that much productive territory will be found farther north and east in this township.

Jackson Township, Wells County, has slowly developed into one of the most reliable productive areas of the main Indiana field. More changes are made necessary on the new map in this township than on any other equal area of the field. The north half of section 4 and all of sections 3 and 5 have proven productive, but the yield is, in general, light. The west half of section 14, and sections 15, 16 and 17, have yielded fair producing wells. The undrilled portion of section 24 shown on the other map has proven quite productive and sections 23, 26 and 36 have yielded more oil than the bores put down previous to 1897 promised. The undrilled portions of sections 19, 29 and 30 have also been developed sufficiently to be classified as designated on the map.

One of the best wells of the township is on the Byall farm on the east half of section 28 . It is a "crevice" or salt water well put down in 1896 by the Slater Oil Co. The first year it did not pay expenses but since then has averaged 12 barrels a day of oil and 700 barrels of salt water. Experience has well proven that it pays to hold on and keep pumping these big salt water wells, even though the first year or two's output is small. On the whole, the prophecy made in 1896, "that in Jackson Township there was much territory which had been condemned by dry holes, which with a fair test might prove productive," has proven true. The tests were made and the output has well repaid the venture. It is always safer to work the undrilled portions of such a township as Jackson, which lies within the limits of known productive territory, than to "wild-cat" on the outside of such limits.

Developments in Huntington County in 1900.—The most important extensions on the north side of the main Indiana field in 1900 were made in the vicinity of Warren, Salamonie Township, Huntington County. One or two bores which developed only salt water were, in the early history of the field, put down to a shallow depth in the Trenton. These stopped the drilling in the southwest corner of the township though the conditions seemed favorable for a fairly productive field and in my report for 1896 it was stated that "there is no reason why oil should not be found in the territory

about Warren." Some of the citizens of that town finally decided to make more thorough tests and, organizing the Warren Oil Co. and securing leases on nearly 2,000 acres, they drilled in their first well in January, 1900, on the Jones farm, south half of section 19, just west of the town limits. The well proved a success, the initial output when put to pumping being 60 barrels daily. As the well was two miles north of known productive territory it created no little excitement. A second bore, 600 feet west, started in at 40 barrels. After the second well came in as a fair producer, the company having accomplished its purpose of proving the presence or absence of oil, sold the two wells and 500 acres of leases west of the Salamonie River to Booth Bros. for $13,000. During the year the new owners sunk four additional bores, all of which were fairly productive. An average record of the bores was about as follows:

Drive pipe	40 feet.
Casing	415 feet.
Top of Trenton	970 feet.
Total depth	1,010 feet.

On October 20 the six wells were averaging about five barrels each.

In addition to the wells on the Jones lease, the Warren Oil Co., during the first half of 1900, put down five bores east of the Salamonie on the northeast quarter of section 19. These proved successful, and they sold the wells and 1,500 acres of territory to McCormick & Co., in August for $13,500. The wells had an average initial output of about 30 barrels each per day for the first week; and on November 1st the six were making a total of 30 barrels daily. The best of the six was No. 2, J. H. Thompson, in which the Trenton was found at 977 feet. Three other wells were put down by the Plum Tree Oil Co. on section 19, close to the river bank, one of which started at 50 barrels.

The oil bearing Trenton about Warren is said to be rather solid and flinty and is not shattered as much by shooting as is more porous limestone. It is void of gas and, as in most other localities in the Indiana field, bears some pyrite, especially in the upper pay streak. The shooting is done with 80 to 100 quarts of nitroglycerine, a less quantity than is generally used on account of the thinness of the pay streak and the shallow depth (about 35 feet) the bores are sunk into the Trenton.

Besides the wells above mentioned a dry hole was sunk on the S. L. Good farm in the northwest of section 20, and another, one mile south of Plum Tree P. O., in section 9, where the Trenton was

found as low as 1,020 feet. These stopped further search in that direction as a dry hole had also been sunk between the two prior to 1900.

Aside from the developments about Warren, the only portion of Salamonie Township producing oil is comprised in the two southern tiers of sections. Immediately south of Warren, a dry hole was drilled on the northwest quarter of section 29 and another on the north half of 32, which has practically condemned those sections. No drilling has been done on section 30, but the southwest of 31 has produced some fair wells. Several bores in section 28 have proven barren; while 33 is as yet untested. In section 27 some light producing wells have been sunk, while 26, to the east, has some better ones, especially on its eastern half. Sections 25, 35 and 36 can be classed as fair to good. The Jonathan and Adam Faust farm of 110 acres in the southeast quarter of section 35 had yielded, up to October 1, 1900, 65,100 barrels, of which the owners received one-seventh as their royalty. The south half of 34 has also produced some fair wells.

In Jefferson Township the limits of the producing territory have not been extended much farther north than shown on the map of 1896, but many of the gaps then undrilled in the two southern tiers of sections have proven productive. Above these tiers the only drilling which has been done is as follows: A dry hole which found top of Trenton at 976 feet was sunk on the J. & W. Brown farm, northeast quarter of section 13. A good strike was made a number of years ago on the Weaver lease* near the center of section 21, but for some reason the surrounding area has not been properly tested. Two bores which resulted only in a showing of oil were sunk on the H. Bowen farm, northeast quarter of section 19, but were soon abandoned. No drilling has been done in the county west of Pleasant Plains. In section 25 drilling has resulted in several dry holes and light wells while the south half of 26 is light. The production in 27 and 28 is only in the south halves and is fair. The south half of section 29 is light to fair producing territory, the top of Trenton running about 1,000 feet.

Only the southeast quarter of section 30 has been drilled, a few fair producing wells resulting. Section 31 remains as before while 32 has proven light over practically all its area. The best section in the township is 33, most of the wells starting at 75 to 100 barrels and falling to 20 barrels in a month, 10 barrels in six months, and

*See p. 80, 21st (1896) Report of this Department.

five barrels in a year. An average record of the bores on this section is about as follows:

Drive pipe	200 feet.
Casing	450 feet.
Top of Trenton	1,005 feet.
Total depth	1,055 feet.

The remaining sections of the lower tier run about as marked on the previous map, all being light to fair producers. Southern Wayne Township may produce some fair wells in the future, but the chances are that elsewhere the limits of productive territory in Huntington County have been well defined.

Developments in Grant County in 1900.—In Grant County the most important developments in 1900 were just southeast of Marion, where a new pool, seven miles from other producing wells, was opened up in January. This was in gas territory, and some of the wells put down especially for oil have yielded much gas. The first bore to yield oil in quantity was on the J. H. Wigger farm, southeast quarter section 16, which started in at about 60 barrels and on October 15th was still yielding eight barrels daily. No. 2, which started in as a big gas well, was closed down and a separator put on, the gas being piped to the Marion Brick Works. In October this well was producing 12 barrels of oil. Nos. 3 and 4, drilled later, produced much gas and little oil, while No. 5 was a fair oil well.

Two old gas wells on the Van Vactor farm in the north half of the same quarter section were cleaned out and shot, when a good show of oil resulted; the gas yield being only sufficient to furnish fuel for pumping the two wells. The success of these wells on the Van Vactor and Wigger leases caused many new bores to be sunk in the territory from which most of the gas had been drained, and also much activity in real estate transactions. The Ohio Oil Co. paid $12,000 for 112 acres along the Mississinewa just north of the Van Vactor lease, and a number of gas companies, which held most of the surrounding territory, began to prospect for oil. Two bores on the M. J. Griffith farm, northeast of section 21, just south of Wigger's, came in as dry holes. One on the L. Schwartz farm, southwest of section 15, was a small producer.

One mile south of the Wigger lease on the west side of the County Infirmary and adjacent lands the Ohio Oil Co. drilled seven wells east of the Mississinewa and three west during the summer. Most of these came in as fair producers, starting at 25 to 40 barrels daily.

The record of the No. 1 Jones, on the west bank of the river, in the extreme southwest corner of section 21, was as follows:

Drive pipe	92 feet.
Casing	381 feet.
Top of Trenton	883 feet.
Total depth	986 feet.

Eight or ten other wells were, in the autumn, drilled in on the north half of section 28, Mill Township. Several of them produced much salt water with the oil, and were pumped from the beam. Trenton was found in all between 870 and 885 feet. All but one were fair oil producers, but were pumped under difficulty as they had to hold back 30 to 50 pounds pressure of gas in the bores and pump without loss. One or two had to be closed down on account of the large quantity of gas. The two farthest south were on the Winslow farm and started in at about 30 barrels each per day.

On the James Coulter farm, northeast quarter of section 24, about three miles east of the Mississinewa pool, three bores were put down during the year, all of which produced oil. Two previous bores had been sunk for gas. The record of No. 5 was as follows:

Drive pipe	175 feet.
Casing	427 feet.
Top of Trenton	1,020 feet.
First pay streak	1,040 feet.
Total depth	1,058 feet.
Initial production	30 barrels.

On the Nelson farm, just north in the southeast quarter of section 13, two dry holes were drilled. One made a good showing of oil, but soon exhausted when put to pumping. By the first of January, 1901, the daily production of the 35 producing wells southeast of Marion was about 260 barrels; and was slowly increasing. The Indiana Pipe Line Co. had put in a field station on the Wigger lease and had prepared for a much larger output which is sure to come, as soon as the gas pressure lowers sufficiently in the surrounding territory as yet undrilled. The only drilling for oil in Center and Mill townships outside of those mentioned resulted in a dry hole just south of Marion on the northwest quarter of section 20, and two bores on the Neal and Myers farms, sections 11 and 3, in the north part of Center Township, which yielded much gas and a large quantity of oil. Nothing was done toward developing the latter on account of the quantity of gas, but the showing is sufficient to justify the belief

that this portion of the township will also, in the near future, be quite productive of oil.

In Monroe Township, Grant County, just east of the developments above mentioned, an old gas well on the northwest quarter of section 13, which had showed oil for some time, was drilled deeper and began producing about 10 barrels daily. In the southeast quarter of section 25 on the east line of the same township, three or four small producing wells have also been drilled in.

Van Buren Township has heretofore furnished most of the oil produced in Grant County, and the chances are that it will continue to do so for some time to come. Many new bores have been sunk since the former map was issued and while they have not greatly increased the limits of productive territory, they have aided materially in filling up the gaps thereon shown. The drilling in the township in 1900 was especially active.

The north half of section 1 has proven good territory, some of the wells on the Conway and Barnes leases starting in at 80 to 100 barrels daily. Sections 2 and 3 are light throughout, though their north halves have not yet been fairly tested. All of section 4 has become fair territory, while 5 and 6 have remained good. The late bores put down in section 7 have been only fair producers. The northeast quarter of section 9 has developed some fair wells, but otherwise sections 8, 9, 10, 11, 12, 13, 14 and 15 remain as formerly designated. Section 16, which was formerly regarded as barren except on its southeast quarter, has produced some fair wells on the northwest quarter. All of section 17 and most of 18 may now be regarded as fairly productive. In sections 19 and 20 the only new developments are in the southeast quarter of 20, which contains some light wells. The west half of 21 has also become fairly productive; the east half being dry or undrilled. Sections 22 and 23 remain good, the initial yield in the latter being generally much the better. Sections 25, 26 and 27 have developed nothing in their south halves, the north halves remaining light. The north half of section 28 has likewise proven light, while that portion of 29 drilled is light or dry. The remaining sections along the south line of the township have not as yet been tested, but will probably show up as light to fair territory as soon as the gas pressure is sufficiently lowered.

Developments in Blackford County in 1900.—In Blackford County the developments which have increased the limits of the productive territory have been mainly in Washington and Licking townships. Drilling in Harrison Township since 1897 has made necessary no changes on the map issued in that year.

In Washington Township, the southeast quarter of section 6 has produced some fair wells, the remaining sections of the tier holding up good as formerly designated. The northeast quarter of 7 is good, the southeast quarter fair, the west half light. All of sections 8 and 9 have developed into fair territory. In 9, the record of the average bore on the Kelly and Cunningham leases is about as follows:

Drive pipe	185 feet.
Casing	365 feet.
Top of Trenton	1,008 feet.
Total depth	1,062 feet.

Two or three big salt water wells have been struck which, at the end of six months, were yielding eight to 10 barrels of oil and 800 barrels of salt water daily.

Sections 10 to 14, inclusive, remain as shown on the former map, with the exception of the north half of 11, which is practically barren. The northeast quarter of 15 is good, the top of Trenton being found at 1,012 feet. The remainder of the section is light. In sections 16, 17, 18 and 19 some important developments were made in 1900. All of 16 and the south half of 17 is light, while the north half of 17 and all of 18 and 19 is fair. Sections 20, 21 and 22 may be classed as light, the wells starting in at five to 30 barrels each. No drilling resulting in oil has been done on 23, 24 and 25 since the former map, while that done on 26, 27 and 28 has resulted only in dry holes or salt water. Section 29 is light to fair territory. The good results of holding on and pumping a salt water well for months are shown in a well on the Isaiah Miller lease, northwest of 29. This was drilled in in April, 1899, and for 15 months yielded 1,600 barrels of salt water daily and but little or no oil. On September 1, 1900, it began to pump oil, and between then and January 1, 1901, yielded an average of seven barrels a day. In this bore the top of Trenton was struck at 1,021 feet, and the total depth was 1,074 feet. Section 30 is light territory, while the sections of the lower tier in the township are as yet undrilled. They will, however, doubtless yield more or less oil in the near future.

Among the new developments in the Indiana Trenton rock oil fields in 1900, those in the vicinity of Hartford City, Licking Township, Blackford County, take a high rank. A good showing of oil had, in 1898 and 1899, made its appearance in several of the gas wells near that city, but the gas pressure was too strong to attempt to develop a paying oil production. By September, 1900, this pressure had decreased so much that, when a well bored for gas near the northwest edge of the city reached the porous limestone it began to

yield oil in large quantity. It was located on the northeast quarter section 10 (23 north, 10 east) and drilled in on September 16. The record of the bore was as follows:

Drive pipe	185 feet.
Casing	300 feet.
Top of Trenton	999 feet.
Total depth	1,044 feet.

The oil bearing stratum was 24 feet below the top of Trenton. The production was about 200 barrels during the first 36 hours. Eight tanks of oil were produced the first month. On October 23, the output was 25 barrels of oil and about 100 barrels of salt water daily.

The usual excitement of a good strike in new territory immediately followed. In a fortnight, seven rigs were up, six of them being within 20 rods of the first producer, while three were on an area 75 feet square. The second well finished was on the Rapp lease, southeast quarter of section 3, one-third of a mile northeast of No. 1. It had an initial output of 200 barrels, and yielded much gas, but was soon down to a 40-barrel producer. The others close to the first well came in as fair producers, yielding from 20 to 100 barrels each and a large supply of gas. In those producing the most gas, the Trenton was struck "high" or at a depth of 990 to 995 feet. Some of the operators had much trouble in securing a market or other lawful use for the gas, and several of the wells were closed for some time on this account. The two pay streaks usually found were, in most of the bores about Hartford City, merged into one, forming a layer 20 or more feet thick of solid oil producing rock. Several of the wells which, when first drilled, promised to be good producers, after shooting yielded gas only. By November 15, eight producing wells were completed, the aggregate yield of which was 250 barrels daily. On December 1st, 15 bores had been finished, all within a radius of one mile of the first well. Six of these had been closed down on account of too strong a gas pressure. The other nine were yielding 325 barrels daily.

By the first of January, 1901, the gas pressure had gone down in a number of the wells and the daily yield had increased to 450 barrels or more. In one well, yielding 40 barrels and much gas, the oil yield was increased to 100 barrels after the gas pressure disappeared. There is little doubt but that the pool will increase in size and gradually connect with that to the north and northeast. In the words of a

prominent operator, "Hundreds of good oil wells are at present shut down as gas wells in the vicinty of Hartford City. They have for two or three years shown much oil and yielded little gas, but nothing has been said about it by the owners of the leases on which they occur. The larger gas companies are quietly leasing all the prospective oil territory they can get, for they know that the days of the gas yield are few, and that the oil is sure to take the place of the more volatile fuel."

ISOLATED TRENTON ROCK OIL PRODUCING AREAS.

Outside of the main oil field there are in Indiana several smaller areas which are producing petroleum in commercial quantities from the Trenton limestone. Some of these, as those near Peru, Broad Ripple and Alexandria have been productive since 1897. Others, as the Parker, Randolph County and Fisher, Hamilton County pools, were developed in 1900.

THE PERU FIELD IN 1900.—But two or three bores were put down in 1900 in the Peru field proper as mapped in the 1897 report. They were small producers, starting in at 10 to 15 barrels. Many of the old wells sunk on town lots have been abandoned. Much more money was expended in this field than was ever gotten out of it. The rock was more porous than at any other locality in the State where the Trenton has produced oil. As a result the stored product was much sooner exhausted, the production quickly dropping from 100 to 200 barrels down to five or 10. The outcome of the Peru field has proven the fallacy of many small companies attempting to operate successfully in a limited area. The expenses are bound to exceed the profits unless the output is phenomenal.

A new pool was opened up in Erie Township, Miami County, on October 13, 1898. The first well was sunk about two and a half miles east of Peru in the angle north of the main line of the Wabash railway, and east of the Chili branch of the Detroit Division of the Wabash. The center of the field is about one-third of a mile from each line and one-half mile north of the Wabash River. A part of it lies in the Richardsville Reserve, Peru Township. The wells are on the bluffs of the river, 75 to 90 feet above low water.

In 1899 12 or 15 wells were completed, but three of which were dry, the average initial production being about 22 barrels. In 1900 drilling was more active, and on October 15 there were 35 producing wells in the field. Of these, 23 were owned by the Crawford Oil Co., while the Wabash Labor Co. and the St. Charles Oil Co. owned six

each. The first well in the field on the Baker lease, section 18, found the Trenton at 960 feet, had an initial production of 50 barrels, and at the end of two years was making four barrels daily.

On the E. Butts lease, 20 wells were in operation on October 15, 1900. Of these 11 produced 4,200 barrels of oil from September 15 to October 15. Mr. Butts receives one-fourth royalty and leases locations 500 feet apart each way instead of definite tracts of land, as is usually the custom. In this way he is getting his just proportion of the riches underlying his land. The average record of the bores put down on the Butts leases was about as follows:

Drive pipe	70 feet.
Casing	505 feet.
Top of Trenton	940 feet.

But one pay streak is said to occur in this field and that is usually 10 to 15 feet below the top of Trenton, the wells being sunk about 25 feet in. But about one-half the wells are shot, and the quantity of nitro-glycerine used is small, being but about 60 quarts. The drift is deeper farther east, being in a few of the wells more than 200 feet. No gas occurs in the field, that used as fuel being piped from a distance. During the winter of 1900-1901, this supply was cut off and coal and wood took its place. The oil produced is piped eastward to Rich Valley, thence to Laketon, and finally to Whiting, where it is refined.

At Kellar's or Rich Valley, in the edge of Wabash County, a few miles east of the above pool, but three new wells were drilled in 1900. One of these was dry, the other two small producers.

The following is the output by months of the Peru and Rich Valley fields for the year 1900:

PRODUCTION OF THE PERU AND RICH VALLEY, INDIANA, OIL FIELD BY MONTHS FOR THE YEAR 1900.

January	16,883 97
February	13,665 11
March	16,206 53
April	19,395 33
May	21,683 41
June	25,307 46
July	23,931 61
August	23,839 73
September	19,727 83
October	21,145 07
November	17,834 04
December	17,668 76
Total	237,288 85

THE ALEXANDRIA FIELD IN 1900.—Oil operations about Alexandria, Madison County, were at a standstill from the spring of 1898 to April 1, 1900, on account of the anti-waste gas law. At the latter date an old gas well on the Armstrong lease, northwest quarter section 6 (20 north, 7 east), three and a half miles south of the town, which for some time had been showing oil, was drilled deeper, cleaned out and shot. The depth of the well was increased from 963 to 1,014 feet, a little too deep, as it proved, for it began to yield about 300 barrels of salt water and 35 barrels of oil a day, and kept up this yield throughout the year. In addition it produced at a low pressure about one million cubic feet of gas a day which was separated through the casing and piped to Alexandria. A second gas well, one-third of a mile northeast, was drilled down to a depth of 1,005 feet, but when shot produced, in addition to much oil, four million cubic feet of gas, and was not pumped. No. 3, 10 rods west of No. 1, was a failure. It produced only a trace of oil and quite a supply of gas, and was plugged. No. 4, 10 rods east of No. 1; completed October 18, proved a fair oil well and a small gas producer. The record of its bore was as follows:

Drive pipe	174 feet.
Casing	400 feet.
Top of Trenton	923 feet.
Total depth	998½ feet.*

Four other bores were drilled for oil on the Brunk lease, one-third of a mile northeast of the No. 2 Armstrong. In them Trenton was struck at 913, 908, 914 and 906 feet, respectively. Two were drilled in 85 feet, but all produced much gas and little oil.

In the west part of Alexandria near the Big Four railway station five wells which had been closed since 1898 were put to pumping in August and made about 15 barrels each. One and a quarter miles east of the town on the S. H. Buck lease, northwest quarter of section 20 (21 north, 8 east), a well completed September 13 started in at about 50 barrels daily. The record of the bore was as follows:

Drive pipe	110 feet.
Casing	385 feet.
Top of Trenton	924 feet.
First pay streak	967 feet.
Total depth	1,018 feet.

*This well was plugged about the close of the year, as the oil produced was not sufficient to pay for operating.

But little gas was found, and only 20 to 30 barrels of salt water was produced daily. Several other small producers were drilled in the immediate vicinity later in the season.

The strike of the year which created the most excitement in the Alexandria field was the J. E. Lippincott well on the Heritage lease, northeast quarter of section 7 (21 north, 7 east), one and one-half miles northeast of Alexandria. It came in the middle of June as a good gas well, having been bored 27 feet into Trenton. It was closed and the derrick taken down, but as soon as the gas was turned into the pipe line it ceased flowing and the well filled with oil. The derrick was rebuilt and the well drilled 85 feet into "sand," and after shooting produced at the rate of 1,200 barrels of oil a day for a few days. It soon dropped to 200 barrels, and on October 15 was down to about 65 barrels daily. The well showed much gas at times, and was closed down on several occasions. A special gas line was laid to it and the gas piped to several factories. The oil was readily pumped when the gas pressure was kept below 25 pounds. A second well on the same lease, one location south, produced much gas and no oil, while a third one, put down by a rival company, just 50 feet west of No. 1, produced a large amount of gas and about 40 barrels of oil daily. When shot, it was claimed that the space between the two bores was broken through, and when one well was pumped the other showed no oil. A fourth bore, 15 rods north of No. 1, produced only gas.

On the W. P. Blake lease, northwest quarter of section 16 (20 north, 8 east), five wells sunk in 1898 and closed by injunction till June, 1900, were producing in October a total of about 500 barrels per week. The average depth of the Trenton was 916 feet, and each well was drilled in about 100 feet, the first pay streak being found at 35 and the second at 65 to 70 feet in. Not enough gas was produced for fuel. On the S. E. Peck farm, southwest quarter of section 9 (20 north, 8 east), were two other wells closed in 1898 which became good producers in 1900. A well starting in at 200 barrels daily was completed on the Nicson lease, section 23, Monroe Township, in November. A former bore on the same lease had produced gas only.

Near Gaston, Washington Township, Delaware County, about seven miles northeast of Alexandria, three wells were drilled in on the W. H. Broyles lease, northeast quarter of section 36 (22 north, 8 east), in the fall of 1897. They produced large quantities of both gas and oil, and were closed by injunction on March 12, 1898. Four wells, located on adjoining farms to the south, were closed at the same time. The three wells on the Broyles lease struck Trenton at 940, 935 and 933 feet, respectively. In October, 1900, Howland &

Co. put down a fourth well, 24 rods north of No. 2, striking Trenton at 937 feet. In order to shut off the gas they used 10-inch drive pipe and 6¼-inch casing. Inside of the latter 5⅝-inch casing was used clear down to the oil. Two pay streaks yielding gas were found, the first 25 to 45 feet, the second 65 to 80 feet in. The inner casing was sunk to a depth of 1,019 feet, or below the gas "pay." A packer was put in below the gas and one above. Below the gas 18 feet of oil rock was found, the oil being raised through 2-inch tubing without waste of gas. The outfit was quite expensive, but was fairly successful, the output of the well being about 40 barrels daily, which flowed by heads. An arrangement was utilized by which enough gas for running the engines was secured from the supply held between the packers. A second well, using the same process, was being drilled on the lease at the close of the year. It is thought by some operators that after these wells have been pumped a while and the oil has become partially exhausted for a distance around the foot of the bore, the gas will find its way down and up inside of the tubing, the experiment thereby proving a failure. Mr. Broyles received from Howland & Co. $2,000 bonus and one-sixth royalty for 82 acres of his farm, and the same amount for a second 80 acres, from the American Window Glass Co., the latter company agreeing to pay also $100 per year for each gas well drilled, from which the gas was piped away for use.

All together, the operations in and about Alexandria during the year were very successful and the chances are that much good oil territory will be opened up in the near future. The growth will be gradually toward the northeast until the main petroleum field is reached. The results of the past few years have shown that the oil will remain until the gas is practically exhausted, when it can be secured without loss of the more volatile fuel. It is worse than folly to waste the gas in an attempt to prematurely secure the oil. Whenever possible separators can be used and the gas piped to some main where it can be utilized. By such means only can these two fuels be properly conserved and made to be of the greatest and most lasting utility to the people of the State.

In the following table is shown the output of oil from the Alexandria field by months for the year 1900:

PRODUCTION OF THE ALEXANDRIA, INDIANA, OIL FIELD BY MONTHS FOR THE YEAR 1900.

January	......
February	859 59
March	2,423 16
April	3,613 89
May	4,995 72
June	6,006 19
July	6,134 83
August	6,723 62
September	4,686 90
October	5,372 13
November	10,277 41
December	8,800 94
Total	59,894 38

THE PARKER, INDIANA, OIL FIELD IN 1900.—Near Parker, Monroe Township, Randolph County, four bores were sunk for oil in the first half of 1900, all of which were small producers, starting in at five to 35 barrels each. There was no gas to deter operations and the output held up well, averaging 10 barrels per well at the end of two months. Experienced operators could probably have opened up quite a strip of territory, but two or three dry holes in the latter part of the season stopped the drilling.

A few miles east of the Parker pool, near Selma, Liberty Township, Delaware County, a gas well was cleaned out, drilled deeper and shot in July. A strong flow of gas resulted for a few days and then it began producing oil at the rate of 35 barrels daily and also a large amount of water. A second gas well which was likewise cleaned and shot started at five barrels, but no successful drilling resulted during the year.

Near Smithfield a well on the G. H. Canady farm, northeast quarter of section 27, Liberty Township, started in August at 40 barrels and was producing the same amount on October 15th. A second bore on the same lease produced only gas. On the W. Lewis farm, same section, another bore started at 20 barrels. In section 23, Liberty Township, a wildcat bore on the M. Dunkin farm proved a dry hole, while another on the J. Dunkin lease yielded gas only, as did another bore on the Cecil farm in section 24.

East of Muncie five miles, on the Delaware County Infirmary farm, section 8, Liberty Township, an old gas well was cleaned out and shot, when it began producing 50 barrels; and when two months old was yielding 30 barrels. A second bore started in at 15 barrels. By the last of November there were nine producing wells in the Parker and

Smithfield pools which were yielding a total of 120 barrels a day. They were scattered over a large area which promises to develop into fair producing territory before the close of another year.

THE FISHER, HAMILTON COUNTY, POOL IN 1900.—Near Fisher, Hamilton County, the Indianapolis Gas Co. completed a well in May, 1900, which had an initial production of 60 barrels. It was on the Wiseman lease, section 25, Fall Creek Township, a mile and a half northeast of the Kincaid well which the year before had produced quite an amount of oil. The new well was shut down for some time on account of lack of tankage, pipe line connections, etc., but when put to regular pumping in July it produced 50 barrels a day for a month or so. A second well on the Hartly lease near-by was a small producer, starting in at 15 barrels. A bore on the Wyant farm, same section, proved a dry hole, as did also one on the Thacher farm, section 26. Four other bores finished later in the season on the Booth and Kinnerman leases, section 24, and the Brandon and Wilson leases, section 25, proved dry, practically putting an end to the hopes of finding good producing territory of any size in that vicinity.

THE BROAD RIPPLE FIELD IN 1900.—No extensions of importance were made in the Broad Ripple, Marion County, oil field in 1900. But eight wells were completed. Of these two, located on the Gardner and McCormick leases, were dry. The others were mostly small, the total initial production of the six being only 95 barrels, or an average of 16 barrels per well. The total production of the Broad Ripple field in 1900 was 30,194 barrels, as against 51,000 in 1899, a loss of nearly 41 per cent. The yield in 1900 was less than one-third what it was in 1898, when the field produced 102,087 barrels.

The following table shows the production by months in 1900:

PRODUCTION OF THE BROAD RIPPLE, INDIANA, OIL FIELD BY MONTHS FOR THE YEAR 1900.

January	2,942 68
February	1,489 21
March	3,449 72
April	3,106 96
May	2,874 52
June	4,399 22
July	1,779 71
August	2,374 62
September	2,342 38
October	2,082 83
November	1,444 81
December	1,907 69
Total	**30,194 35**

STATISTICS OF THE INDIANA TRENTON ROCK PETROLEUM FIELDS IN 1900.

While the year 1900 was not characterized by any great strikes or notable extensions of productive territory in the Trenton limestone field of Indiana, it was nevertheless the banner year in the oil industry of the State. The price of iron pipe and other supplies which had risen rapidly during the year previous, declined materially, so that the cost of a productive well was much less.

The price of oil, while much lower at the end of the year than at the beginning, averaged for the year 9 cents more per barrel than in 1899. The price at the beginning of the year was $1.12. By February 26 it reached the maximum of $1.21, which it held until April 2, when it began to decline. On May 21 it had fallen to $1.00, and by June 6 to 90 cents. It held this price until August 9, when it began to slowly go down again, reaching 74 cents, the minimum price, on November 13. At the close of the year it was selling at 78 cents, with a tendency toward a further rise. The average price for the year was 96½ cents as against 87½ in 1899.

The total production of Trenton rock petroleum in Indiana in 1900 was 4,912,675 barrels which, at the average price of 96½ cents, amounted to $4,740,731. Compared with 1899, this was an increase in production of 1,104,961 barrels, or 29 per cent. Owing, however, to the higher average price, the amount received by the producers was $1,408,981, or 42 per cent. more than in 1899.

The first of the following tables gives a complete record of the monthly production of petroleum from the Trenton limestone fields of Indiana for the 10 years beginning January 1, 1891, and ending December 31, 1900. The second table shows the annual production, the average yearly price, and the total value by years for the same period:

TOTAL PRODUCTION OF TRENTON LIMESTONE PETROLEUM IN INDIANA FROM 1891 TO 1901, BY MONTHS.

[Barrels.]

MONTH.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
January	6,171	15,841	111,824	259,000	300,568	365,582	290,746	317,014	297,291	353,451
February	5,981	18,946	96,025	232,107	230,559	211,743	309,922	272,780	220,440	302,493
March	5,159	24,794	134,549	282,376	310,303	386,586	341,961	325,301	290,257	364,590
April	4,973	26,184	146,493	287,330	352,077	395,032	328,779	310,034	325,774	381,804
May	5,757	31,033	186,939	321,502	397,001	417,963	340,023	311,208	344,831	426,363
June	8,136	40,888	209,616	333,479	403,569	434,167	369,803	320,477	334,282	446,492
July	10,809	49,203	221,666	327,349	434,376	422,968	375,249	314,861	329,086	437,087
August	11,603	56,109	248,353	345,031	420,132	407,238	371,921	332,777	347,621	466,127
September	16,500	66,034	245,615	319,588	409,169	415,675	362,528	326,264	332,283	418,716
October	19,029	95,699	252,568	339,424	393,153	394,283	408,179	319,490	326,781	467,521
November	20,801	129,270	245,607	304,030	373,789	337,331	430,958	200,644	326,802	406,684
December	21,715	144,067	236,038	337,450	361,436	362,164	423,069	300,457	332,266	441,347
Total	136,634	698,068	2,335,293	3,688,666	4,386,132	4,680,732	4,353,138	3,751,307	3,807,714*	4,912,675

PRODUCTION OF TRENTON ROCK PETROLEUM IN INDIANA FROM 1891 TO 1901, WITH VALUE.

	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
Total production (barrels of 42 gallons)	136,634	698,068	2,335,293	3,688,666	4,386,132	4,680,732	4,353,138	3,751,307	3,807,714	4,912,675
Total value at wells of all oils produced, excluding pipeage	$54,787	$260,620	$1,030,882	$1,774,260	$2,807,124	$2,954,411	$1,871,849	$2,228,276	$3,331,750	$4,740,731
Value per barrel	$0 40	$0 37	$0 45	$0 48	$0 64	$0 63	$0 43	$0 59⅜	$0 87½	$0 96½

*This sum in the table on page 12, Report of this Department for 1899, was 11,000 barrels greater, that being the amount of Corniferous rock petroleum produced at Terre Haute in that year and included in the monthly production of Trenton rock oil.

From the above tables it will be seen that the largest production in any one month was in October, 1900, when 467,521 barrels were produced. The total production for the ten years reached the enormous amount of 32,750,359 barrels, for which was received $21,074,690, or an average of more than $2,100,000 per year. This did not include the amount used for fuel and other purposes in the field.

In the following table there is shown the number of wells put down in the Trenton limestone fields of Indiana for petroleum in each month since June, 1891:

NUMBER OF WELLS COMPLETED IN THE INDIANA TRENTON LIMESTONE OIL FIELDS FROM 1891 TO 1901, BY MONTHS.

YEAR.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1891........	......	......	......	......	......	......	6	6	15	15	15	8	65
1892........	11	13	18	13	17	19	17	30	25	52	33	47	295
1893........	20	30	31	36	45	47	47	55	27	72	56	76	542
1894........	90	103	103	80	110	107	84	123	100	107	97	85	1,189
1895........	61	45	81	111	122	153	132	140	129	106	102	85	1,267
1896........	76	90	86	136	148	150	113	121	70	58	66	66	1,180
1897........	41	35	40	47	49	52	60	45	55	89	119	54	686
1898........	41	23	29	43	38	55	53	80	72	82	92	86	694
1899........	75	48	68	64	87	99	77	104	106	120	106	106	1,060
1900........	112	66	97	143	162	164	159	149	135	151	114	104	1,556
Total....	......	......	......	......	......	......	......	......	......	......	......	......	8,534

From the above table we learn that 289 more bores were sunk for oil in the Trenton rock oil fields of Indiana in 1900 than in any preceding year. The high price of the product was the leading factor in causing this increase of activity. Whenever petroleum sells close to the dollar mark or above, the profit of production is sufficient to keep the drills steadily at work. On January 1, 1901, there were 5,480 wells producing oil in the State, as against 4,336 on January 1, 1900—a gain of 1,144 for the year. The table also shows that up to January 1, 1901, 8,534 bores had been sunk to Trenton rock within the State for petroleum, so that 3,054 had either proven dry or were abandoned previous to the date mentioned. The number abandoned in 1900 was 197, or just 50 less than in 1899, while the number of dry holes drilled during the year was 215, or 110 more than in 1899. Of the total number of bores drilled, 13.8 per cent., or 3.8 per cent. more than in 1899, were dry.

The following table gives the

TOTAL NUMBER OF DRY HOLES DRILLED IN THE INDIANA TRENTON LIMESTONE OIL FIELDS FROM 1891 TO 1901, BY MONTHS.

YEAR.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
1891........	......	......	......	......	......	......	......	2	5	4	3	1	15
1892	2	6	6	2	3	4	2	3	3	18	6	21	76
1893........	7	10	10	6	14	6	11	9	5	14	10	9	111
1894........	19	14	24	14	13	13	9	21	15	14	8	17	181
1895........	7	4	13	16	22	20	15	23	12	12	9	13	166
1896........	10	13	6	28	26	20	14	19	4	4	6	8	158
1897........	8	9	7	12	5	16	11	9	16	11	18	8	130
1898........	14	4	2	13	9	6	7	10	12	8	13	16	114
1899........	5	9	14	5	5	7	12	9	12	14	8	5	105
1900........	10	6	15	16	25	21	31	21	15	20	22	13	215

The final table shows the

NUMBER OF PRODUCING WELLS AND NUMBER OF DRY HOLES DRILLED IN EACH OF THE TRENTON OIL PRODUCING COUNTIES OF INDIANA IN 1900.

COUNTY.	Producing Wells.	Dry Holes*	Total.	Percentage of Dry Holes.
Wells	543	37	579	6.4
Blackford........................	166	36	202	17.8
Jay	64	41	105	39
Adams	120	13	133	9.8
Grant	227	13	240	5.4
Huntington.......................	134	13	147	8 8
Madison	17	38	55	69
Miami............................	45	4	49	8.2
Marion	7	3	10	30
Wabash	2	3	5	60
Delaware	9	4	13	31
Hamilton.........................	2	7	9	77.7
Randolph.........................	5	3	8	37.5
Total.......................	1,341	215	1,556	
Average	....	....	....	13.8

*This column includes bores sunk for oil which yielded gas.

From the statistics given it will be seen that the year 1900 was by far the best in the history of the Trenton rock oil fields of Indiana. Drilling was more active, there being 289 more bores sunk than in any preceding year. The percentage of dry holes was greater than in 1899, but this was due mainly to the active wildcatting in prospective territory outside the known limits of the main field. The average price of the product was high enough to keep the drill going,

and yet not too high as compared with its real value. The initial production was, on the average, much less than in previous years. This goes to prove that the days of the gusher are practically over in the older portions of the main field where most of the bores were sunk. It is better for the practical producer that this is true. A well starting at 200 barrels or more a day creates an excitement and a rush for territory that in the end proves harmful to all concerned. Large bonuses are paid out and big risks taken which are foreign to territory whose wells are small but sure producers. As has been stated in my former reports, one large well will not make any man a fortune; twenty small ones may in time. The yield of the large producer will quickly grow much less; that of the twenty small ones will hold out for a long time. There is yet room for thousands of wells in the known productive territory. At present prices eight to ten wells pumped by one power and yielding on an average but two or three barrels each per day, will prove a paying investment.

It is a good omen for the future of the oil industry in Indiana that so many bores are being sunk each year in the old producing territory of Wells, Adams and other counties. The risks of the operator are much fewer. Moreover the chances that the greater portion of the stored product will eventually be brought to the surface are much greater where a bore is sunk on every 10 acres than where only one is sunk on each 40 or 80-acre tract. Were a bore sunk at regular intervals on each 8 or 10 acres of productive territory the profits in the end would be more sure and much greater than where the present haphazard method of drilling is followed.

CORNIFEROUS ROCK PETROLEUM.

Petroleum in commercial quantities has been found in the Corniferous rocks of Indiana in three different and widely separated localities, namely: at Loogootee, Martin County; Terre Haute, Vigo County, and west and northwest of Medarysville, Jasper County. At Terre Haute this petroleum has been produced since 1889. At the other points the first production was in 1899.

The Corniferous formation is the lowest or oldest division of the Devonian system in Indiana, being represented in the State by sandstones with a maximum thickness of 20 feet, which are thought to correlate with the Schoharie group of New York, or by limestones five to 65 feet in thickness correlated with the Upper Helderberg. At Loogootee the oil bearing rock is a sandstone; at the other localities, limestone. Above the oil bearing rocks of this formation will always be found a deposit of brown and black shales, varying in thickness from 90 to 160 feet. These are the Hamilton and New

Albany or Genesee shales. They not only form the close grained cover which has prevented the total evaporation of the volatile portions of the petroleum, but they are undoubtedly the original source of the petroleum itself.

These shales, when first deposited, were largely composed of the remains of plants and animals, which, by the action of slow destructive distillation mentioned on a preceding page, were changed into bitumens. The Genesee shale is rich in these bitumens,* and when set on fire will burn until they are consumed. Where the underlying rock is a porous limestone or sandstone, the oil and gas, which have been separated from the shale during the thousands of years which have elapsed since its formation, have accumulated. It is these accumulations or reservoirs which have been struck at the points above mentioned. Similar reservoirs doubtless occur in many portions of the area which the black shale underlies, but they will be found only where the Corniferous limestone or sandstone is porous enough to retain in large quantities the gaseous and liquid bitumens.† The gas at Petersburg and Loogootee is only the more volatile part of the oil which has arisen into the higher portions or anticlines of the porous rocks. Where these rocks are found low, the oil or salt water will occur, but there is much less likelihood of salt water being found in quantity than in the Trenton limestone of the main Indiana oil field.

The Genesee shale, and its underlying oil bearing rocks, occur only in the western half of the State. Here it has been recognized in all the deep bores drilled west of its eastern outcrop. This outcrop extends from the Ohio near New Albany in a northeasterly direction through Floyd, Clark, Scott, Jefferson and Jennings counties, then northwesterly through Bartholomew, Johnson, Marion, Boone, Clinton, Carroll and White counties. The shale forms the surface rock of an area eight to 15 miles wide in these counties or those adjacent on the west. It is also known to be the formation immediately underlying the drift over quite a large area of the two northern

*A paper treating of the bitumens of this shale was published in the report of this department for 1896, pp. 108–119. As a result of numerous experiments, the author found that 8.5 pounds of the black shale yielded by distillation 45 gallons of gas, which, when burned as an illuminant, proved to be 22 candle power in quality. In Scotland 60,000,000 gallons of crude oil are annually produced by distilling a similar shale, while at the same time 25,000 tons of sulphate of ammonia, a valuable fertilizer, is formed as a by-product.

†As in the Trenton rock oil fields, there are absolutely no surface indications by which one can locate, with any degree of certainty, productive wells. The only thing to do is to sink a bore through the black shale to the underlying Corniferous rocks. If accurate surface levels of the first dozen or more producing wells are determined, one can readily ascertain the dip of the oil-bearing stratum, and thereby lessen the chances of failure in future bores.

tiers of counties in the State. At Loogootee the Corniferous oil bearing rock is about 500 feet below the surface. At Terre Haute, which is much farther west of its outcrop, the oil occurs 1,630 feet below; while at Medarysville, near the eastern outcrop, the depth to the oil bearing stratum is only 100 to 110 feet.

THE TERRE HAUTE POOL IN 1900.—The Phœnix well at Terre Haute is the oldest and the best oil well in the State of Indiana. For 12 years it has yielded an average of more than 1,000 barrels per month. When the drill first struck the oil bearing stratum on the night of May 6th, 1889, the flow was so great that quite a lake of oil accumulated around the derrick, and there was some alarm lest a destructive fire should result. The drill was then pulled out of the well, and as soon as the end left the mouth of the drive pipe, a solid stream of oil four and a half inches in diameter shot into the air a distance of forty or fifty feet. While running at this rate there was probably a little over a barrel a minute pouring from the well, and when the pressure decreased from the first spurt, which lasted only fifteen minutes, the flow steadied down to a four and a half inch stream spurting about three feet above the mouth of the well. A tank with a capacity of twenty barrels was put under the pipe, and it was filled to overflowing in just twenty-two minutes. This great flow soon began to decrease, and in a few months had reached an average of 35 barrels per day, which it has since maintained. The output of the well in 1900 was 12,090 barrels, or 1,015 barrels per month, except in April, when a few days were spent in cleaning out the well, the production for the month being thereby reduced to 925 barrels.

Previous to the sinking of the Phœnix well, three or four bores had been put down at Terre Haute, one to a depth of 2,400 feet. In two of these oil in small quantity had been found. The result of the Phœnix strike was like that of every other similar one in the history of the petroleum industry. Hundreds of oil operators from far and near flocked to Terre Haute. Real estate almost doubled in price. Twenty-four new companies were formed, eighteen of which made locations. A dozen or more bores were put down to the required depth within three miles radius of the first gusher, struck the proper stratum, and for the most part found—nothing. Two, within a short distance of the original well, yielded oil in small quantity. The yield of one was soon overcome by salt water. The other continued to produce for five or six years, but was finally abandoned.

No further prospecting was done until 1899, when two bores were completed. One of these, about two miles north and one-half mile west of the Phœnix, was a dry hole. In the other, about 40 rods northeast of the Phœnix, oil was found, which partially filled the bore. Owing to litigation, this well was not pumped until 1900, the output for that year being a little less than 1,000 barrels.

The oil from the Corniferous at Terre Haute is darker colored, more ill smelling and of a greater weight and density than the Trenton rock oil from the main Indiana field. An examination and comparison of samples of the two were made by Dr. Noyes, who reported on them as follows:*

	Terre Haute.				Van Buren.			
	Per Cent.	Specific Gravity.	Degrees, Beaumé.	Flashing Point.	Per Cent.	Specific Gravity.	Degrees, Beaumé.	Flashing Point.
Original oil	....	0.879	30°	....	......	0.853	35°	....
Below 150° C.	....	....	....	....	7.2	0.719	....	Below 20° C
150°-200° C	12.0	0.793	48°	38° C	10.2	0.759	56°	Below 20° C
200°-250° C	14.0	0.825	41°	65° C	10.2	0.799	47°	60° C
250°-300° C	13.6	0.847	36.5°	85° C	12.2	0.826	41°	82° C
300°-350° C	14.8	0.867	32.5°	97° C	14.8	0.844	37°	96° C
350°-390° C	40.6	0.879	30°	45° C	41.8	0.860	34°	38° C
Total distillate	95.0	....	....	....	96.4	....	....	....
Residue by weight	6.2 per cent.				4.5 per cent.			
Sulphur	.72 per cent.				.83 per cent.			

"The oils were distilled rather slowly from flasks with the thermometer in the vapor only. A thermometer filled with nitrogen and graduated to 460° C. was used.

"The oils appear to be quite similar in general character, but there is less of the low boiling products in the Terre Haute oil, and the specific gravity of the oil and of the various distillates is higher. The portion of the Terre Haute oil boiling at 350°-390° deposits considerable amounts of solid paraffines at 15° C. The low flashing point of the high boiling oil must be due to a partial 'cracking' of

* The sample of Trenton rock oil was obtained at Van Buren, Grant County.

the oil. From the results, I calculate the following percentage of naphtha and kerosene contained in the petroleums:

	Terre Haute.	Van Buren.
Naphtha below specific gravity 0.73	None.	10%
Kerosene between specific gravity 0.73–0.83	30%	33%

There is little doubt but that a large quantity of oil occurs in the Corniferous rocks beneath the city of Terre Haute and vicinity, else the yield of the Phœnix well could not have been so uniform and long continued. The porous area or reservoir containing the oil must, however, be narrow, and this bore probably struck it at just the right point to get the best results. Some people who know little or nothing of the geology of Indiana believe that the Phœnix well struck a crevice, which extends to the main oil field of the State. Such belief is, of course, preposterous, as the Corniferous rock which contains the oil at Terre Haute, outcrops before the main oil field is reached, and is not pierced by any bore sunk in that field. Moreover, it is a younger and much thinner formation than the Trenton limestone, and for that reason there is little chance of developing an oil output near Terre Haute in any way comparing to that of the main Indiana field.

THE LOOGOOTEE OIL FIELD IN 1900.—In the spring of 1897 a well was drilled into the Corniferous sandstone at Petersburg, Pike County, 25 miles southwest of Loogootee, which resulted in a good gas producer, having since supplied most of the citizens of Petersburg with fuel. Six other bores were soon afterward sunk in that vicinity, in all of which either oil or gas was found in small but not commercial quantities. These bores led to the organization of the Loogootee Prospecting Co. at Loogootee, Martin County, which proposed to prospect for oil or gas in the vicinity of that town. Their first bore, a short distance south of the town, was intended to reach Trenton limestone, but at a depth of 1,682 feet drilling was for some reason stopped near the base of the Hudson River limestone, or in the top of the Utica shale. The well should have been drilled to a depth of 2,000 feet, in order to have reached and thoroughly tested the Trenton rock. At a depth of 478 feet a good showing of both oil and gas were found in a thin stratum of Corniferous sandstone. About 15 gallons of oil a day were produced. On April 2, 1900, 100 feet or more of oil was standing in the bore.

The showing made by this first bore was deemed sufficient to justify the drilling of another well about one-quarter of a mile east of No. 1. In this gas was struck at a depth of 505 feet, the stratum of sand being three feet thick. The output of gas was about 400,000 cubic feet per day. The third bore, a quarter of a mile east of the second, was on a ridge whose surface level was 32 feet higher than that of the second bore. In it the gas bearing sand was struck at 527 feet, and was eight feet in thickness. About one half million cubic feet of gas daily resulted, but no oil.

In the fourth bore, put down on the Larkin lease, 1,500 feet east of No. 3, the surface level was 15 feet lower. The productive sand was 16 feet thick, its top being 513 feet below the surface. When finished, on November 13, 1899, it began flowing water, gas and oil, yielding about 250,000 cubic feet of gas and 12 barrels of oil per day. On April 12, 1900, it was yielding about six barrels per day, natural flow. No. 5, sunk 700 feet east from No. 4, at the same level, was dry, none of the productive sandstone having been found at 562 feet when the bore was abandoned. This completed the results of the first season's work.

In 1900 the first well completed was a dry hole on the Fields farm, a mile northeast of No. 4 above mentioned, no sign of the productive stratum of sandstone being encountered. The second was on the Cannon lease, and was distant about one-quarter of a mile southeast of the gas well (No. 3) last drilled. It was finished February 18, the sandstone being 17 feet thick and struck at a depth of 478 feet. Its initial output, when pumped, was four barrels. It was shot with 10 quarts of nitro-glycerine, being the first of the wells so treated. After shooting, it flowed 30 barrels of oil a day for 10 days, then fell to 20 barrels, which it was yielding on April 12. A small quantity of gas was escaping on that date. The flow of the oil was natural and by heads at intervals of 10 to 12 minutes. The striking of this second productive well created much excitement and an active scramble for territory by oil men from widely different localities. A number of rigs were at once erected and drilling began in earnest.

Three miles east of the No. 4, or first oil producing well, a bore on the O'Brien lease, section 17, Perry Township, found the sand at 390 feet, but only Blue Lick water was produced. A second bore on the Cannon lease, 600 feet south of the new oil producer, was dry. The sandstone, struck at 483 feet, was only two feet thick, dense and very hard. Another bore on the Larkin lease, only 500 feet northeast from No. 4, was drilled in on April 10. Fourteen

feet of sand was found at 527 feet below the surface and the bore developed a 10-barrel producer. Still another bore, sunk between the Larkin and Cannon wells, had an initial production of 50 barrels. This, the fourth oil well in the field, was the last one drilled in 1900, all the others yielding either Blue Lick water or gas or being wholly dry.

Those of which we have an account in this office are are follows:

Thos. Mehan lease, section 18, Perry Township, three-quarters of a mile north of producing wells; sand struck at 501 feet, white, thin; well dry, though afterward filled up with Blue Lick water struck at 445 feet.

Chas. Gootee lease, section 1, Perry Township, two and a fourth miles south of the Larkin wells, developed 10 feet of close grained sandstone and was dry.

O. J. Clark lease, one-third of a mile south of Larkin wells, two bores sunk, each producing a million cubic feet of gas but no oil.

J. M. Hall lease, section 35, Barr Township, Daviess County, three miles southwest of Loogootee; first sand 30 feet thick, close grained, dry; second sand, at 493 feet, yielded two and a half million cubic feet of gas.

J. Dible lease, section 2, Barr Township, Daviess County, one million cubic feet of gas.

S. Smith lease, section 3, Barr Township, Daviess County; dry hole.

J. McCord lease, section 26, Barr Township, Daviess County; sand eight feet thick, large gas well.

John Graham lease, near Glendale, Harrison Township, Daviess County, 13 miles southwest of Loogootee; sand found at a depth of 950 feet. Good showing of oil, no gas.

M. E. Haggerty lease, five miles south of Loogootee; dry hole.

McBride Bros. lease, four miles east of Loogootee; dry hole.

In all 26 bores were put down in the Loogootee field during 1900. Of these three produced oil, 10, gas, the remaining 13 being dry. The results show that the productive stratum of sandstone is not to be relied upon. It does not appear to be continuous but is in pockets. It varies much in thickness and also in closeness of texture, in some places being soft, quite porous and productive; in others, hard, close grained and barren. On account of its pockety nature and thinness, the supply of oil from any given area of this Corniferous sandstone will never equal that from any similar area of the main Trenton limestone field of northeastern Indiana.

The Loogootee Prospecting Company, to whom all credit is due for bringing about the development of the field, have done well with

their venture. They owned, at the close of the year, the four producing oil wells and four of the gas wells, besides having control of much of the best prospective undrilled territory. Their stock, of which 1,200 shares were issued at $10 each, was selling at $60 per share when any was on the market.

The oil produced at Loogootee is very similar to that found at Terre Haute, being ill smelling, dark in color, and possessing a specific gravity of 32° Beaumé. It is shipped by the Indiana Pipe Line Co. to Jeffersonville, Indiana, and Louisville, Kentucky, where it is used mainly for fuel. The output of the producing wells by months for the year was as follows:

PRODUCTION OF THE LOOGOOTEE, INDIANA, OIL FIELD BY MONTHS IN 1900.

January	142 20	August	769.08
February	144.42	September	701.08
March	713.67	October	759.08
April	544.89	November	827.59
May	843.42	December	800.00
June	1,129.91		
July	561.45	Total	7,936.79

THE JASPER COUNTY OIL FIELD IN 1900.*—During the past two years active development has been carried on in Jasper County, Indiana, with the result that a considerable area of valuable oil territory has been disclosed. The oil is found in a limestone which, without doubt, is a continuation of the Corniferous limestone formations at present producing oil in the Canadian fields, and at Terre Haute in Vigo County, Indiana; the limestone being easily recognized throughout a large area of southern Michigan and western Indiana, but being entirely absent in the eastern and central portions of the latter State. The formation is nearest the surface in the section of Indiana which has since developed into the Jasper County oil field and is found in the most productive portions of this field at approximately 100 feet below the surface.

The history of the Jasper County field dates from 1865, when a company was organized in New York to exploit certain oil territory, supposed to exist in the Kankakee swamps of Indiana. This company was organized during the great oil excitement in Pennsylvania and adjoining states, but no records remain of any active development

* Mr. C. K. MacFadden, of Geneva, Indiana, to whom much of the credit is due for the opening up of the Jasper County field, furnished most of the data for this report on that field I have re-arranged his paper and have added to it in places additional data which I gathered when I last visited the field. For the most part, however, the wording is his own. —*W. S. B.*

undertaken by this original company. The next interest shown in this section was in 1893, when a well drilled on the W. J. Swisher farm, six miles west of Medarysville, southeast quarter section 33 (31 north, 5 west), Gillam Township, was completed, which produced a considerable amount of oil. This well was drilled by the owner of the farm to provide water for his stock. Not finding water at the usual depth the well was continued to a depth of about 85 feet, when a flow of oil was encountered which, according to reports, flowed intermittently, its production at certain periods ranging as high as 10 barrels daily. The oil was found to be a good lubricant, and for a number of years the owner of the well obtained a fair income from the sale of it at approximately $10 per barrel. Shortly after the Swisher well was completed a number of test wells were drilled in the immediate neighborhood, but in the light of present development it would seem that none of them penetrated the Corniferous limestone to a sufficient depth to obtain oil in any quantity.

The recent history of the field began in July, 1899, when a company, composed of a number of practical oil producers and known as the Interstate Oil Company, commenced active work. They leased approximately 36,000 acres of land, 26,000 of which they obtained from B. J. Gifford at one-eighth royalty, the only condition being that they put down a bore to the oil producing rock on each section of land, one well to be sunk every 60 days, until the tract was drilled over. After purchasing the oil right on the original Swisher farm, the company sunk a bore 700 feet northwest of the first well, which resulted in a two-barrel producer. Additional wells were completed in section 33 until by the end of the year 1899 a considerable acreage had been proven to be productive territory. About this time the development of the district was brought to the attention of a number of English capitalists known as the Byrd Syndicate, Lmt., of London. That syndicate made a careful investigation of the property of the Interstate Oil Company, and finally purchased the leases and 19 producing wells, paying therefor the sum of $150,000. The new company immediately began extensive operations, and by the close of 1900 had more than 100 producing wells in operation. Several other companies were formed soon after the Interstate Company sold its territory and most of the unleased land near by was quickly taken up, either by lease or direct sale.

In eastern Jasper, western Pulaski and the counties to the northward, the New Albany or Genesee brown and black shales immediately underly the drift and are encountered in sinking wells for water. As already noted, these shales are rich in bitumens, both

oily and gaseous. In the yard of J. P. De Selmes, on the northwest of the northeast quarter of section 34 (31 north, 5 west), about a mile northeast of the Swisher well, a bore sunk for water in 1893 a few feet into the shale produced gas enough to supply several stoves. It was used in the cooking stove for six months, but as no separator was put on to shut off the water the latter finally found its way into the stove. In April, 1900, the well, after being primed and pumped a few strokes, would flow water for 10 or 15 minutes and at the same time allow a large amount of gas to escape. This when set on fire would burn with a flame several feet high as long as the water flowed.

The Corniferous limestone or oil bearing rock underlying this shale in the productive area of Jasper County is a hard gray limestone which, in a number of test wells which have been drilled through the formation, has been found to be approximately 40 feet in thickness. The upper 20 feet, however, constitutes the oil producing portion of the limestone, and in this 20 feet are found several bands or pay streaks of porous rock which enlarge into crevices with considerable regularity. These crevices are often lined with pyrites of iron and lime crystals. Crevices have been found in quite a number of the producing wells which were two or three feet in thickness. In case a well, while being drilled, encounters one of these crevices, it will often produce a considerable quantity of oil without a shot of nitro-glycerine, but almost without exception it has been found desirable to place a torpedo of about 20 quarts in such position in the formation as to cover 10 or 12 feet of rock, the result invariably being to greatly increase the well's production. One of the large glycerine companies has a magazine in this district and provides the Jasper County producer with the necessary explosive.

The usual formation encountered in drilling a Jasper County well is as follows: Drift, consisting of sand, clay and loam, 50 feet, under which is encountered a bed, 45 to 55 feet in thickness, of close grained black shale which forms an impervious cover for the Corniferous limestone reservoir. This black shale or slate does not cave in drilling, it thus being necessary to use but a short length of drive pipe to shut off the drift formation. The operators use for this purpose 5⅝ inch casing, and by driving it a sufficient distance into the black shale shut off the surface water. With the usual form of portable drilling machine employed in the Jasper County district, an expert crew has completed a bore in the remarkably short time of 23 hours actual drilling time, it thus being evident that the cost of a well is a very small sum.

The oil obtained is unlike any other product found in the Ohio and Indiana oil districts, it being of a black or very dark green color and of a gravity which ranges from 17 to 21. Its thickness and low gravity is without doubt largely due to the shallow depth at which it is found, the more volatile portions having long since escaped through their overlying formations. The oil on examination is found to have a cold test of about zero F. and a fire test of over 300°. It has a good viscosity test and is universally used throughout the Jasper County district for lubricating purposes. It is associated with a strong sulphur water of which a large amount is usually encountered whenever a crevice is penetrated. There is usually but little gas found in the district except immediately upon the completion of a new well, when, for several days following, a considerable quantity of gas is often discharged. Further development may disclose an area in which gas will be found in larger quantity and several wells which are expected to be finished to the Trenton limestone during the summer of 1901 may develop gas or oil horizons in the two producing formations lying under the Corniferous limestone, namely: the Clinton formation, producing oil in small quantities, 10 miles southwest of the Jasper County development, and the Trenton limestone.

There has been but little excitement shown in the development of the Jasper County field, due to the fact that the territory is controlled in large blocks, thus largely eliminating rivalry between owners of the adjacent properties such as furnishes the activity so noticeable in the Trenton limestone areas of Indiana. Moreover, the wells are generally small producers, running only from two to five barrels each. This, however, is not always the case, as several wells drilled on the Syndicate's properties in section 28 (31 north, 5 west), Walker Township, and in section 33 (31 north, 5 west), Gillam Township, having resulted in producers whose first day's output ranged from 10 to 100 barrels or more. The largest well completed in the district is on the south half of the southwest quarter section 28, Walker Township. This well, when completed, without a shot, gave a yield of approximately 200 barrels in 24 hours when pumped in a rather primitive manner with one of the drilling machines. It is quite possible that this well would have yielded a much larger amount had it been pumped with a standard pumping rig such as is used in the deeper territory of the State.

Outside of the immediate vicinity of the first producing well, other drilling has been done as follows: On the W. Austin farm, one and a quarter miles southwest of Wheatfield, northeast quarter section

35 (32 north, 6 west) a bore was sunk to a depth of 203 feet in January, 1900. It is claimed that no black shale was encountered and only a strong flow of sulphur water resulted, the vein of which was struck in limestone at a depth of 185 feet.

On the John Perry farm, two miles southeast of Wheatfield, a bore found the oil bearing stratum at a depth of 105 feet, and a fair producing well resulted. A bore which produced gas only was sunk on the J. A. Campbell farm, northeast quarter of section 33 (31 north, 5 west).

Three and a half miles west of San Pierre, on the banks of the Kankakee River, two or three light producing wells have been developed on the farm of M. S. Rogers. The oil from these wells has the lowest gravity of any in the field, and the color is dark green rather than black.

In Railroad Township, Starke County, two or three bores were sunk which produced only a showing of oil. A bore with similar results was drilled a mile south of Medarysville on the land of E. C. Williams.

Three and a half miles southeast of the main producing area, on the land of James A. Low, section 11 (30 north, 5 west), a bore was drilled in June, 1900, to a depth of 700 feet. The oil producing rock was struck at 125 feet, but was barren.

In the immediate vicinity of San Pierre several fairly productive wells have been completed. The first one sunk was on section 9 (32 north, 4 west). In it considerable gas with traces of oil was found, but at a depth of about 125 feet a strong vein of sulphur water was encountered which produced a flowing well. In a second bore in section 18, one and a half miles southwest of No. 1, oil was struck at 122 feet, a small producing well resulting. Two or three other bores were put down in the vicinity of San Pierre which produced oil, but no accurate record of them has been secured.

According to Mr. MacFadden, the total estimated daily production of Jasper County at the close of the year 1900, was approximately 400 barrels. The actual daily production possible is unknown, due to the fact that a market for the oil is as yet wanting, although pipe line service will be installed during the summer of 1901. It is doubtful, however, if the oil can ever be freely moved by means of pipe lines on account of its thickness and heavy weight. What has been sold was hauled in barrels to the railway stations and is said to have brought $5.00 to $5.50 a barrel for lubricating purposes. After the sediment is removed but little difference is said to exist between it and the Mecca, Trumbull Co., Ohio, lubricating oil which brings $10

per barrel on the market. It is claimed that a St. Louis firm has purchased a quantity of the Jasper County product for making an artificial rubber compound, the oil being exceedingly rich in asphaltum and paraffine bases.

There is probably no oil field in the world in which the expense of development is as low as in the Jasper County district. The oil formation lies at an extremely shallow depth and the area which has been found to be petroliferous seems to be fairly uniform in character, resulting in few wells which will not make paying producers. Notwithstanding the small output of the average well, the cheapness with which the territory may be operated, together with the value of the product, makes it possible to operate at a profit wells which produce but one or two barrels daily and it may be confidently expected that the life of the wells will compare favorably with the development in the Corniferous limestone formation in the Canadian oil fields, where many wells have produced oil in paying quantities for the past 25 years. There is little doubt but that the productive territory will eventually be found to extend over a large area to the north and northwestward of present development. In many localities to the southward, a little west of the line of outcrop of the black Genesee shale, the porous Corniferous limestone doubtless occurs. The chances are that in these localities wells producing oil similar to that of the Jasper County field will be drilled in the future but their output will never be large.

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During my trips over the petroleum fields of Indiana in the spring and autumn of 1900, much data was furnished for the foregoing paper and other assistance rendered by the following persons, to whom especial acknowledgments are due: James McCormick, of Hartford City; A. S. Hunt and Alex. McDonald, of Montpelier; L. C. Davenport, of Bluffton; Matthew McCormick, of Warren; J. C. Leach, of Kokomo; Chas. Lockwood, of Peru; C. K. MacFadden and Jas. H. Hardison, of Geneva; Benj. Fulton, of Portland; Dr. A. W. Porter, of Loogootee, and W. B. McNeil, of Wheatfield.

THE

DEVONIAN FOSSILS

AND

STRATIGRAPHY OF INDIANA.

BY EDWARD M. KINDLE.

INTRODUCTION.

The study of the Devonian faunas of Indiana was begun by the writer independently of the State Survey, and a preliminary report on the results accomplished was published* in the spring of 1899. The generous assistance of State Geologist Blatchley has made it possible to continue the work thus begun, and the field work has been extended to the northern Indiana Devonian, about which but little has heretofore been known. The work on the northern Devonian has about doubled the number of species previously known from the Devonian black shale of the State, and has brought to light a new fauna in the Devonian limestone.

In preparing the accompanying report, the writer has kept in mind the needs of Indiana students who may wish to become acquainted with the interesting faunas of our Devonian rocks. The specialist in paleontology will probably find little use for the artificial keys to species which have been prepared, but it is believed that they will be helpful to the beginner. Frequent quotations from other writers have been made for a similar reason, as it is expected that many of those who will use this report will not have access to an extensive reference library, and for their convenience the descriptions of Hall, Meek and others have been fully quoted wherever the material at hand did not permit of so full or complete a description as had been published elsewhere. It has also seemed desirable to quote Hall's original descriptions in many cases of species which were described from Indiana specimens. In all such cases any new observations or variations from the description quoted have been noted after it.

The publication of such papers as Schuchert's work on the Brachiopoda seems to render it unnecessary to give the synonymy of species in a paper of this kind. For the sake of convenient reference to other figures and descriptions, however, one or two citations are usually given after each species.

In addition to the collections of the State Museum and those made for the State survey, the writer has had access to the splendid private

* Bull. Am. Pal., No. 12, 1899, pp. 1-111.

collection of Mr. G. K. Greene during the preparation of this report. To Mr. Greene's generosity he is indebted for the use of many of the specimens here figured. Mr. Taylor, of Hanover, and Mr. John Powers, of Lexington, have also kindly loaned specimens for study. Special acknowledgment is due to Prof. H. S. Williams and to Dr. John M. Clarke, to whom a few specimens were referred for identification or comparison with types. To Dr. Geo. H. Girty, Prof. H. S. Williams and Dr. H. F. Cleland I am indebted for the privilege of examining specimens belonging to the United States Geological Survey. The drawings for the plates were made by Dr. J. C. McConnell of Washington, D. C.

PART I.—STRATIGRAPHY AND FAUNAS.

GEOGRAPHICAL DISTRIBUTION OF THE DEVONIAN.

A large part of the Devonian rocks of Indiana are deeply covered by the drift. With the exception of two somewhat widely separated districts, the Devonian formation throughout the northern two-thirds of the State are buried under a mantle of Drift which varies in thickness from 50 to 400 feet. The Devonian rocks which are not completely covered by the deposits of the Drift may, for convenience of discussion, be referred to three geographical areas. These districts in which Devonian rocks may be studied are separated from each other by considerable areas in which no outcrops of the Devonian occur. They will be designated as the Wabash area, the Pendleton area and the Southern Indiana area.

The attenuated character of the Drift in the southern part of the State permits of frequent outcrops of the Devonian rocks for a distance of 85 miles north of the Ohio. The portion of the Devonian belt outcropping from the Ohio River to the southern part of Johnson and Shelby counties comprises the Southern Indiana area.

The nearest Devonian outcrops to the north of the Southern Indiana area are those of the Pendleton area, about 45 miles to the north of the Johnson and Shelby county sections. About 75 miles to the northwest of Pendleton, Devonian rocks are again found outcropping through the Drift along the Wabash River. The outcrops of the Wabash area are not very numerous, and are confined to a narrow strip of country 10 or 15 miles wide on either side of the river, extending from near Peru to Delphi, a distance of 35 or 40 miles.

Drill records indicate that the Devonian rocks lie immediately below the Drift over a continuous belt of country corresponding in direction with the general strike of the rocks, and extending from

the Falls of the Ohio to Lake Michigan. The drill has also indicated the presence of a belt of Devonian rocks extending east and west across the northern end of the State. With the Sub-Quaternary Devonian, however, we are not concerned except to point out that the areas above referred to do not represent isolated Devonian deposits.

THE SOUTHERN INDIANA AREA.

STRATIGRAPHIC NOMENCLATURE.

Previous studies of the Devonian faunas and stratigraphy in Indiana have nearly all related to the southern Indiana area.* The stratigraphic names which have been used and the correllations which have been made apply directly, therefore, to the Devonian as developed in southern Indiana.

New Albany shale.—This formation is extensively exposed along the bank of the Ohio River in the vicinity of New Albany. It consists there of a fissile black shale, having a thickness of about 100 feet and showing but little variation from top to bottom. It rests upon the Devonian limestone and is terminated above by the Rockford limestone. The shale carries a considerable amount of bituminous matter, and occasionally thin sheets of pure bitumen are seen between the layers of shale. The shale shows a uniform black color on fresh surfaces and scarcely any variation in lithological characters in the southern Indiana area. This uniformity in lithological characters does not hold in the northern part of the State, however, as will be shown later.

Mr. Wm. B. Borden was the first to propose a local geographical name for the formation. In his report on Clark and Floyd counties in 1873† Mr. Borden designated this formation as the "New Albany black slate." In the same report the author states that "it outcrops on the Wabash River at Delphi," Carroll County, Ind. This formation is not a slate, and in the later reports of the State Geologist it has usually been called the New Albany black shale. It seems best to drop the qualifying term "black" in using this stratigraphic name because the formation in Indiana is not always black and is frequently composed in part of brown or drab colored shale in the northern part of the State. The following section taken near Delphi, one of the localities mentioned by Mr. Borden in proposing the term

*For a review of the literature relating to the Devonian in Indiana see Bull. Am. Pal. No. 12, 1899, pp. 88-97, and the paper by Mr. Siebenthal in another part of this report; also "Bibliography of Indiana Paleontology," by E. M. Kindle, 22d Ann. Rep. Dept. Geol. and Nat. Res. of Ind., 1897, pp. 488-514.

†Fifth Ann. Rep. Geol. Surv. of Ind., 1873, p. 158.

"New Albany black slate," illustrates the objection to the word black when applied to this formation:

		Ft.	In.
1.	Drift	7	..
2.	Bluish black shale, sheety and tough	45	..
3.	Drab grayish colored slightly sandy shale	4	6
4.	Band of gray colored concretions	6	14
5.	Drab colored sandy shale	10	6
6.	Bluish gray sandstone	4	10
7.	Drab colored sandy shale	5	6
8.	Covered	8(?)	..
	Devonian limestone.		

The section of a well at South Bend shows 25 feet of brown shale* which corresponds stratigraphically to the drab shale of the above section.

In the southern Indiana area the New Albany shale is very frequently separated from the limestone below it by a band of red clay and limestone pebbles associated with iron ore. This ferruginous clay and conglomeritic band has usually a thickness of from one to four inches. Fish teeth are frequently abundant in the limestone just below the clay band.

The Rockford limestone is present at every point where the top of the New Albany shale has been observed in southern Indiana. It is a ferruginous limestone of brownish or greenish gray color, usually from one to three feet in thickness.

Sellersburg beds.—In a paper published by the writer in 1899† the Devonian limestones in the vicinity of the Falls of the Ohio were recognized as representing two distinct formations, which were named the Sellersburg beds and the Jeffersonville limestone.† The Sellersburg beds constitute the uppermost of these two formations and "include the beds from the New Albany shale down to the lowest beds worked at the cement quarries."‡ The Sellersburg beds comprise a bed of fine grained argillaceous drab grayish colored limestone which is extensively quarried in the vicinity of Sellersburg for cement, and a thin bed of light gray or bluish crystalline limestone above it. The lower drab colored "cement rock" has a thickness of from six to 20 feet in Clark and Scott counties, and does not vary greatly in lithological characters in the region between Lexington and Jeffersonville. The upper limestone, where it can be dis-

* Eleventh Ann. Rep. U. S. Geol. Surv., 1889-90, p. 738.

† Bull. Amer. Pal., No. 12, p. 8.

‡ Bull. Amer. Pal., No. 12, pp. 1-111.

tinguished from the "cement rock," usually has a thickness of from five to eight feet. It shows considerable variation in lithological characters, and in some localities is absent or can not be distinguished from the "cement." At the cement quarry, one and a half miles south of Charlestown, the two divisions of the Sellersburg beds are sharply differentiated as shown in the following section:

		Ft.	In.
1.	Red clay with fragments of black shale	2	..
2.	Crystalline white or light gray crinoidal limestone	6	..
3.	Coarse-grained blue limestone, full of small black pebbles	..	8
4.	Dray gray fine-grained limestone	9	..

Three miles to the north of the above quarry at the quarry of the Standard Cement Company we find the following section:

		Ft.	In.
1.	Surface clay ..... 4 to	5	..
2.	Black shale	1	..
3.	Gray to black conglomerate with black pebbles and chert	..	3 to 15
4.	Hard bluish drab fine-grained arenaceous limestone with much chert	7	..
5.	Drab colored arenaceous limestone without chert.	2	..
6.	Drab colored arenaceous limestone with light colored concretions of chert	1	6
7.	Drab colored arenaceous limestone free from chert	6	..

It will be seen from the above section that no very satisfactory stratigraphic division of the Sellersburg beds as here developed can be made. The same is true of the section exposed at the quarry of the Ohio River Cement Company.

The outcrop along a small stream about one mile west of Oregon shows the "cement rock" directly under the New Albany shale at some points, while at others a light gray crinoidal limestone separates them. Where typically developed this upper limestone often has a great abundance of crinoids. At the Falls of the Ohio it was distinguished by Lyon* as the "encrinital limestone." The local character of this limestone in its typical development, however, seemed to make it preferable to include it with the "cement rock" under the name of the Sellersburg beds. About 35 miles north of the Falls of the Ohio the Sellersburg beds lose their characteristic lithological features and can not be distinguished from the Jeffersonville lime-

*Trans. St. L. Acad. Sci., Vol. I, 1859-60, pp. 612-622.

stone. This blending of the physical features of the two formations is accompanied by a mingling of their two faunas, as will be pointed out in detail later.

Jeffersonville limestone.—The Jeffersonville limestone is the lowest formation of the Devonian as developed at the Falls of the Ohio. It is the "limestone lying between the Sellersburg beds and the *Catenipora* beds of the Niagara."* This formation has, perhaps, its most typical development at the Falls of the Ohio just below the city of Jeffersonville. It shows a continuous outcrop along the north bank of the river from the Pennsylvania Railway bridge at Jeffersonville to the upper end of the Government dyke below Whirlpool point. At the latter locality the Jeffersonville limestone is overlain by about eight or 10 inches of the bluish drab arenaceous limestone of the Sellersburg beds. The Jeffersonville limestone has a thickness of about 20 feet at the Falls of the Ohio. It is a gray or bluish gray crystalline or subcrystalline limestone, occurring both as a massive and a thinly stratified limestone.

The fossil coral reef for which the Falls of the Ohio have long been noted, occurs in the lower part of this formation. *Spirifer acuminatus* and *Spirifer gregarius* are abundant and characteristic fossils of the upper portion of the formation. The upper beds of the Niagara or the Louisville limestone of Foerste lie immediately below the Jeffersonville limestone. The lower part of the latter and the Louisville limestone are well exposed in the Bear Grass Creek quarries just east of Louisville, Ky. The section exposed at the west quarry shows:

1. White to light gray limestone (Jeffersonville limestone) .... 10 feet.
2. Light bluish gray argillaceous limestone (Louisville limestone) .... 35 feet.

Geneva limestone.—North of the Falls of the Ohio 10 or 15 miles, sections which include the Lower Devonian and Niagara rocks begin to show a thin bed of rather soft, dark buff to brownish fine grained magnesian limestone. This formation lies between the Jeffersonville limestone and the Niagara or Louisville limestone. It thickens gradually toward the north and reaches its maximum development along Flat Rock Creek.

The Geneva limestone is generally a massive light buff to chocolate brown saccharoidal magnesian limestone. It varies in lithological

*Bull. Amer. Pal., No. 12, 1899, p. 8.

characters, however. Along Wyloosing Creek, in Jennings County, it is in part a very hard siliceous limestone and was used at one time for mill stones.

The southernmost point at which I have recognized it is at the roadside one quarter of a mile east of Charlestown in the following section:

1. Bluish drab impure limestone.................... 4 feet.
2. Gray subcrystalline limestone.................... 5 feet.
3. Dark buff, rather soft magnesian limestone (Geneva limestone) .... 3 feet.
4. Buffish argillaceous hard limestone with *Halysites catenulatus* near the top........................ 25 feet.

About 10 miles further north the dark buff magnesian limestone has a thickness of seven feet near the sulphur spring, northwest of New Washington. In the vicinity of Vernon it has attained a thickness of 20 feet or more. Along the banks of Flat Rock Creek, which is about eighty-five miles north of the Falls of the Ohio, it has a thickness of about 30 feet.

The name Geneva limestone was first used by Collett in his report on the geology of Shelby County.* The term as used by Collett included the buff or light chocolate colored magnesian limestones exposed along Flat Rock Creek in the vicinity of Geneva. Fossils are extremely rare at most localities in this formation and occur usually as casts when found. Collett referred the Geneva limestone to the Corniferous, but without presenting any paleontological evidence of its Devonian age. The "Rubble stone of Waldron" lying between it and the Waldron shale Collett referred doubtfully to the Corniferous. The fossils collected by the writer from the Geneva limestone leave no doubt as to its Devonian age. No fossils have been obtained from the limestone lying between the Waldron shale and the Geneva limestone, but the unconformity which exists between the latter and the six or eight feet of hard gray limestone below it makes it extremely probable that the latter belongs to the Niagara.

Mr. Foerste† correlates the limestone immediately above the Waldron shale with the Louisville limestone. He proposed for the beds above the unconformity, which was first recognized by him, the name "Shelby bed." This term appears to be a synonym for Collett's Geneva limestone. The latter term was published sixteen years earlier than the name proposed by Foerste, and by the rule of priority the term "Shelby bed" must be referred to the synonymy of the Geneva limestone.

* Eleventh Ann. Rep. Ind. Dep. Geol. and Nat. Hist., pp. 63, 78, 81, 82.
† 22d Ann. Rep. Ind. Dep. Geol. and Nat. Res., pp. 234-235.

Mr. Foerste expressed some doubt as to the age of the four or five feet of limestone immediately overlying the Waldron shale in the vicinity of Hartsville.† Mr. Price, in the area covered by his report, has used the local name "Hartsville bed"‡ or "Hartsville ledge"|| for this bed.

The observations of the writer lead him to correlate this bed in the vicinity of Hartsville on stratigraphic grounds with the Louisville limestone.

The strong development of the Geneva limestone in the northern part of the southern Indiana area is accompanied by a corresponding thinning of the Sellersburg beds and Jeffersonville limestone. These two formations can not be distinguished in Bartholomew County and their total thickness does not generally exceed ten feet. The rocks of these two formations do not outcrop along Flat Rock, and if present, they are buried under the Drift. Their greatly reduced thickness in the nearest sections to the south make it probable that the dolomitic Geneva limestone has entirely supplanted them in the Flat Rock Creek sections.

SECTIONS.

The Ohio Falls Section.—At low water the entire Devonian section is exposed in the bed and the north bank of the Ohio between Jeffersonville and the lower part of New Albany. The direction of the river here is normal to the strike of the rocks. The rapids known as the "Falls of the Ohio" occur where the river crosses the Devonian limestone.

The New Albany shale forms a continuous outcrop along the river from near the lower end of New Albany for about three-quarters of a mile. Between the waterworks pumping station and the mouth of Falling Run, the shale extends from 20 to 30 feet above low water and the exposure extends back from the water 80 to 190 feet. The shale here is cut by a very regular set of east and west joints, nine-tenths of which run within 5 or 6 degrees of due east and west. Occasionally a joint diverges from an east and west line as much as 20 degrees. The joints are usually from 6 to 18 feet apart. Sometimes they are much closer, and rarely they converge, cutting out a wedge-shaped section of shale. There is also a set of north and south joints, but they are not so regular and well developed at this locality as the others.

† 22d Ann. Rep. Ind. Dep. Geol. and Nat. Res., p. 241.
‡ 24th Ann. Rep. Ind. Dep. Geol. and Nat. Res., p. 111.
|| 24th Ann. Rep. Ind. Dep. Geol. and Nat. Res., p. 125.

Above the pumping station the New Albany shale is hidden by alluvium almost to the K. & I. bridge. The shale outcrop begins again just below the K. & I. bridge and continues almost to the mouth of Silver Creek. At the north end of the Government dam above Silver Creek an isolated outcrop of the shale occurs in the river bed which shows the lowest layer in the New Albany shale. Here certain layers of the tough black shale contain great numbers of *Schizobolus concentricus*.

At low water a considerable area of limestone is exposed on each side of the Government dam above the mouth of Silver Creek. Nearly all of the rock here exposed belongs to the highest division of the Sellersburg beds or the "Encrinital limestone" of Lyon. Crinoid heads occur in this limestone in great abundance, together with corals and a few brachiopods. The thickness of the bed is probably not more than four feet. This bed extends from the Indiana side to Sand Island. At the upper edge of the outcrop above Sand Island the "cement rock" is exposed, lying just below the gray crinoidal limestone.

The rise of the strata toward the east brings to view the lower part of the Sellersburg beds and the upper part of the Jeffersonville limestone at a point about 200 yards below the lower end of the Government jetty. The section exposed here shows:

1. Bluish drab arenaceous limestone—"cement rock," (Sellersburg beds)	3 feet.
2. Bluish gray, subcrystalline limestone (Jeffersonville limestone)	7 feet.

At the upper end of the jetty the section exposed in the river bank shows:

	Ft.	*In.*
1. "Cement rock" (Sellersburg beds)	..	8
2. Massive gray limestone	6	..
3. Blue to gray limestone in strata 10 inches to 3 feet thick	6	..

Spirifer acuminatus is a common fossil in No. 2 of this section, which belongs to the upper part of the Jeffersonville limestone.

In a previous paper* by the writer it was proposed to designate the fauna of the Jeffersonville limestone as the *Spirifer acuminatus* zone of the Eodevonian. Later studies of the geologic range and geographic distribution of the Devonian species of the State have seemed to fully justify the selection of this species for that purpose.

* Bull. Am. Pal., No. 12, p. 110.

In the section at the Falls of the Ohio, however, this species appears to be limited to the upper part of the Jeffersonville limestone. *Spirifer gregarius* is the most abundant species in the middle beds of the Jeffersonville limestone at the Falls of the Ohio, while the lower beds are, for the most part, a mass of corals. A band of limestone five or six inches in thickness is made up almost exclusively of the silicified shells of *Sp. gregarius.* It may be traced almost continuously for more than half a mile along the outcrop on the north bank of the river above the jetty. At Whirlpool point it is about 10 or 12 feet above low water.

Near the upper end of the Government jetty the following fossils were obtained from three feet of the lowest limestone exposed at low water:

Pentamerella arata r., *Spirifer gregarius* r., *Spirifer varicosus* r., *Stropheodonta demissa*, *Stropheodonta perplana* r., *Eunella lincklaeni*, *Modiomorpha myteloides* r., *Holopea* sp , *Pleurotomaria* sp., r., *Proetus crassimarginatus* c., *Proetus microgemma* r., *Conocardium cuneus* a , *Blothrophyllum* sp., c., *Favosites hemisphericus* c., *Zaphrentis giganteus* a.

The two feet of hard gray limestone immediately above the bed containing the above noted fossils shows the following association of species:

Actinopteria boydi r., *Atrypa reticularis* c., *Callonema bellatulum* c., *Callonema imitator* ? c., *Chonetes mucronatus* c , *Conocardium cuneus* a., *Cyathophyllum rugosum* c., *Cyrtina hamiltonensis* r., *Dalmanites anchiops* var. *sorbrinus* r., *Dalmanites selenurus* r. *Glyptodesma occidentale* r., *Modiomorpha affinis* a., *Modiomorpha myteloides* a., *Schzophoria striatula* ? r., *Proetus crassimarginatus* c., *Ptychodesma* sp. r., *Orthothetes chemungensis arctistriatus* r., *Stropheodonta demissa* c., *Stropheodonta perplana* r., *Turbo shumardi* c., *Zaphrentis giganteus* c.

About six feet above the last station the species obtained were:

Spirifer acuminatus c., *Atrypa reticularis* c, *Chonetes mucronatus* c., *Proetus crassimarginatus* ? c, *Stropheodonta hemispherica* c. *Stropheodonta demissa* c.

The Jeffersonville limestone shows a nearly continuous outcrop from 10 to 15 feet thick between the Government jetty and the J., M. & I. bridge. Above the bridge it continues to outcrop at low water as far up as the end of the upper bridge.

Near the head of the mill race above the J., M. & I. bridge the "cement rock" outcrops and the following section is exposed:

	Ft.	In.
Bluish drab argillaceous limestone with *Chonetes yandellanus*	..	8
Hard blue limestone with Spirifer acuminatus	..	6
Bluish gray limestone	6	..

Lime was formerly burned from the Jeffersonville limestone above the J., M. & I. bridge.

On the Kentucky side of the river the Sellersburg beds form the bed of the river in the vicinity of the J., M. & I. bridge, where they are worked for cement. A small amount of collecting here afforded the following species:

Atrypa reticularis a, *Chonetes yandellanus* a, *Leiorhynchus quadricostatum* c, *Proetus* sp., *Spirifer oweni* a, *Spirifer segmentus* c, *Spirifer* r, *Stropheodonta demissa*

Cement quarries.—The following lists of species from the Sellersburg beds represent the fauna of the *Spirifer granuliferus* zone:

The following section is exposed at the cement quarry just west of Watson:

		Ft.	In.
1.	Surface clay	3	..
2.	Black shale	..	18
3.	Arenaceous cherty limestone	5	18
4.	"Cement rock"	9	..

The species obtained from the "cement rock" (4) of the above section are the following:

Athyris fultonensis a, *Atrypa reticularis* c, *Chonetes yandellanus* a, *Spirifer byrnesi* c, *Spirifer granuliferus* a, *Spirifer iowaensis* c, *Spirifer varicosus* a, *Stropheodonta demissa* a, *Stropheodonta hemispherica* c, *Fenestella* sp., *Lichenalia* sp. c, *Michelinia favistoidea* r.

The residual clay from the "cement rock" at the Watson quarry furnished the following species:

Athyris spiriferoides? *Athyris fultonensis*, *Atrypa reticularis* a, *Camarotoechia congregata*, *Chonetes yandellanus?* a. *Meristella haskinsi*, *Pentagonia unisulcata*, *Rhipidomella livia*, *Paracyclas elliptica*, *Phacops rana*, *Schizophoria striatula*, *Spirifer granulosus*, *Spirifer oweni*, *Spirifer segmentus*, *Spirifer varicosus*, *Zaphrentis* sp.

At Speed & Co.'s cement quarries near the center of lot 132 one

and three-quarter miles northeast of Speed Station the section exposed is given by Mr. Siebenthal as follows:

1.	Soil	2 feet.
2.	New Albany Black shale	3 feet.
3.	Black buckshot clay	1 foot.
4.	Soft buff arenaceous rock	1 foot.
5.	Cement rock	16 feet.

The cement rock of this section afforded the following species:

Chonetes yandellanus a, *Atrypa reticularis* c, *Orthis* sp., *Camarotoechia tethys* r, *Spirifer granuliferus* r, *Spirifer segmentus* c, *Spirifer varicosus* r, *Stropheodonta demissa* r.

The surface clay of this quarry furnished the following:

Athyris fultonensis a, *Atrypa reticularis* a, *Chonetes yandellanus* a, Crinoid stems a, *Loxonema hydraulicum* r, *Proetus* ? r, *Spirifer byrnesi* r, *Spirifer euruteines* r, *Spirifer granulosus* a, *Spirifer varicosus* r, *Stropheodonta demissa* c.

The cement quarry one and one-half miles south of Charlestown shows the following section:

		Ft.	In.
1.	Red clay with fragments of black shale......2 to	6	..
2.	Crystalline white or light gray crinoidal limestone	6	..
3.	Coarse-grained blue limestone full of black pebbles	..	8
4.	Drab gray fine-grained limestone (cement rock)..	9	..

The fauna of the cement rock here does not vary from that listed in connection with the section described above.

Utica.—The Lower Devonian and Niagara limestones are well exposed along the river front above Utica. The Niagara limestone here has long been used for the manufacture of lime. The Utica lime works, owned by J. B. Speed & Co., manufacture from 5,000 to 8,000 barrels per annum.

Section at the lime quarry north of Utica:

1.	Gray crystalline limestone with *Atrypa reticularis*, *Stropheodonta demissa* and crinoid stems abundant	6 feet.
2.	Gray limestone with *Spirifer gregarius* abundant..	3 feet.
3.	Gray crystalline limestone with corals very abundant	10 feet.
4.	Argillaceous buffish close-grained limestone with *Halysites catenulatus* at the top	10 feet.
5.	Hard blue limestone	20 feet.

No. 5 of the above sections is used for lime. Nos. 1, 2 and 3 belong to the Jeffersonville limestone, while 4 and 5 represent the Louisville limestone (Niagara). The limestone here is said to make a good building stone as well as good lime. The piers of the J., M. & I. bridge were built in part of stone from the Utica quarries.

The Sellersburg beds are not exposed at the quarries. The old fields to the north and west of town, however, afford excellent collecting ground for the fossils of this formation.

Charlestown.—The Jeffersonville limestone forms the bed of the small stream flowing through the west part of Charlestown. The Sellersburg beds and the New Albany shale constitute the surface rocks of the higher land about Charlestown. The red clay resulting from the decay of the former is the source of the beautifully preserved fossils for which Charlestown has long been noted.

East of Charlestown about one-third of a mile at the roadside occurs the following section which is of interest because it is the southernmost section in which the Geneva limestone has been noted:

1.	Bluish drab impure limestone	4 feet.
2.	Gray subcrystalline limestone	5 feet.
3.	Dark buff rather soft magnesian limestone (Geneva limestone)	3 feet.
4.	Buff hard argillaceous limestone with *Halysites catenulatus* near the top	25 feet.

Oregon and New Washington sections.—Oregon lies about six miles northeast of Charlestown. The Sellersburg beds retain their characteristic lithological features in the vicinity of Oregon, but they are thinner than at Charlestown.

The following section is exposed in the road on the south side of Oregon:

		Ft.	In.
1.	Black shale	?	..
2.	Light gray crinoidal limestone	..	15?
3.	"Cement"	7	..
4.	Blue and gray limestone (Jeffersonville limestone)	15	..

The following section occurs three-quarters of a mile northeast of Oregon. With the exception of 1 and 2, which outcrops in the wagon road, the section was taken 150 yards below the wagon bridge:

		Ft.	In.
1.	Black shale	1	..
2.	Dark gray impure limestone (cement)	5	..
3.	Shelly bluish drab limestone	6	..
4.	Gray limestone with *Spirifer acuminatus*	4	..

		Ft.	In.
5.	Drab gray impure limestone with *Chonetes yandellanus*, etc.	5	..
		5	..
6.	Gray limestone with corals	4	..
7.	Hard, flinty limestone, conglomeritic in places with pebbles of chert, quartz and metamorphic rock and shell and coral fragments	..	18
8.	Gray limestone with *Zaphrentis giganteus* and other corals	10	..
9.	Light gray limestone with *Halysites catenulatus Pentamerus* sp., etc.	6	..

This section is of especial interest because of the bed of conglomerate which has not been noted in any other section at this horizon. The absence of the Geneva limestone from this section is another local peculiarity of interest.

About three miles southeast of the above section in tract 145 the Geneva limestone shows a thickness of eight or 10 feet at the big spring just north of the New Washington and Charlestown road.

In the vicinity of New Washington the drift shows a considerable thickness. The well on Miss Fannie Bowers' land one-half mile west of New Washington passed through:

Drift clay	25 feet.
Black muck	3 feet.

The limb of a tree was struck at a depth of 20 feet, and a bowlder lower down.

Just east of New Washington the section exposed in the road shows:

1.	Light buff sandy looking magnesian limestone with a few crinoid stems and corals (Geneva limestone)	3 feet.
2.	Hard gray limestone	5 feet.

Two miles northwest of New Washington at the cave one-quarter of a mile above the sulphur spring is the following section:

1.	Dark gray coralline limestone	5 feet.
2.	Buff sandy looking magnesian limestone (Geneva limestone)	7 feet.
3.	Hard gray limestone (Louisville limestone)	9 feet.
4.	Bluish sandy shale (Waldron shale)	6 feet.

The small cave at this point is in the comparatively soft Geneva limestone, the Devonian and Niagara limestones forming its roof and floor.

Lexington and Hanover sections.—Hanover marks the extreme eastern limit of the Devonian along the Ohio and lies about 10 miles northeast of Lexington. Opposite the railroad station at Lexington the following section is exposed:

		Ft.	In.
1.	Black shale	6	..
2.	Ferruginous conglomerate	..	2 to 3
3.	Bluish limestone with *Tropidoleptus carinatus*, etc.	..	20
4.	Drab colored sandy limestone	2	..

The beds three and four of the above section afforded the following species:

Chonetes yandellanus a, *Tropidoleptus carinatus* a, *Spirifer granulosus* c, *Stropheodonta demissa* c, *Roemerella grandis* r, *Phacops rana* r, *Proetus canaliculatus?* *Stictopora* sp., *Cystiphyllum* sp. ?

At a small quarry at the side of the railroad and about 400 yards north of the station the Jeffersonville limestone is well exposed. From the upper beds here the following fossils were collected:

Schizophoria striatula a, *Rhipidomella vanuxemi* a, *Spirifer byrnesi* c, *Spirifer euruteines* c, *Stropheodonta hemispherica* c.

Just below the bed containing the above fauna occur the following typical Jeffersonville limestone species:

Spirifer acuminatus a, *Stropheodonta demissa* c, *Stropheodonta hemispherica* a, *Platyceras erectum* r, *Stictopora* sp.

South of Lexington one-half mile, the "cement rock" outcrops along the railroad five or six feet thick. This is the northernmost point at which the Sellersburg beds have their typical appearance. The following species were collected at this locality:

Atrypa reticularis c, *Athyris fultonensis* r, *Camaratoechia tethys?*, *Spirifer byrnesi* a, *Spirifer euruteines* r, *Spirifer segmentus?* r, *Spirifer varicosus* a, *Aulopora* sp., *Chaetetes arbusculus* r, *Coleolus aciculum*, *Hyolithes* sp., *Macrocheilus carinatus* r, *Microcyclas* sp., *Modiomorpha concentrica* r, *Paracyclas ellipticus* r, *Proetus canaliculatus*.

About three-quarters of a mile east of Lexington the New Albany shale outcrops in the bed of a small branch on Dr. Davis's farm. The black shale here contains the following fauna. The fossils are abundant and occur in strata three or four feet above the Sellersburg beds:

Chonetes lepidus c, *Leiorhynchus quadricostatus* a, *Styliola fissurella* a.

Two miles west of Hanover, near Big Spring on the Lexington and Hanover road, about 20 feet of Devonian limestone outcrops on the west side of the creek. *Tropidoleptus carinatus* is the predominant species in the uppermost beds here, while *Spirifer acuminatus* is the most abundant fossil a little lower down. The limestone forming the bed of the creek at this point is a mass of corals comparable in abundance with those at the Falls of the Ohio. The Jeffersonville limestone outcrops in the road in the west part of Hanover near the residence of Mr. G. W. Taylor. Its thickness was not ascertained.

A buff magnesian limestone 10 or 15 feet thick outcrops at the top of the river bluff around the edge of Hanover College campus. No fossils were found in it but this bed is supposed to belong just below the horizon of the Jeffersonville limestone and to represent the Geneva limestone.

Northwest of Hanover about six miles and just west of Smyrna church is the following section:

1.	Buff colored magnesian limestone showing a pitted and cavernous face on weathered surfaces (Geneva limestone)	5 feet.
2.	Hard gray limestone	7 feet.

About one mile west of Smyrna church is the following section:

1.	Thin bedded gray limestone full of fossils (Jeffersonville limestone)	6 feet.
2.	Buff magnesian limestone (Geneva limestone)	4 feet.
3.	Covered	8 feet.
4.	Hard gray limestone	1 foot.

Loose fragments of coarse brownish sandstone containing Devonian fossils are scattered about the fields in the vicinity of Smyrna church. Careful search failed to discover this sandstone in position. Its fossils seem to indicate that it represents the remnants of a local bed belonging near the base of the Jeffersonville limestone.

The Muscatatuck and Big Creek sections.—The sections here described include representative sections occurring on or near the east fork of Muscatatuck River and Big Creek. The general direction of these streams is east and west, directly across the strike of the Devonian formations which they traverse.

The westerly dip of the New Albany shale brings the top of the formation nearly to drainage level at the wagon bridge over the

Muscatatuck one mile south of Crothersville. The section exposed here in the bank of the river is as follows:

1. Hard gray limestone with concholdal fracture (Rockford limestone) .... 5 feet.
2. Fissile black shale with *Lingula spatulata?* abundant.

On the north side of the Muscatatuck, just west of the B. & O. S. W. Railway, the Devonian limestone just below the New Albany shale was formerly extensively quarried for building stone. The quarry is now abndoned, the stone, like most of the other Devonian limestone in Indiana, having failed to stand the effects of frost action.

The Sellersburg beds have entirely lost the lithological features which characterize them in Clark and southern Scott counties. The beds which correspond in stratigraphic position to them are usually bluish gray heavy bedded limestones.

The face of the cliff along the creek three or four hundred yards southwest of the quarry shows the following section:

1. Black shale ....1 to 3 feet.
2. Heavy bedded blue to gray limestone.............. 50 feet.
3. Chocolate colored sandy looking magnesian limestone (Geneva limestone) .... 5 feet.

Just east of Deputy, at the old limestone quarry the section exposed is the following:

1. Blue to gray heavy bedded limestone, with the lower three or four feet very arenaceous in places 12 feet.
2. Gray limestone with *Spirifer acuminatus*........... 6 feet.
3. Covered .... 5 feet.
4. Bluish gray limestone full of corals................. 6 feet.
5. Chocolate colored sandy looking magnesian limestone (Geneva limestone)....................... 5 feet.

The upper 12 feet was quarried for building and foundation work.

West of Paris crossing about one and one-half miles, the New Albany shale and a few feet of the underlying limestone are exposed at a small quarry on the south side of the road. The following fauna was found in the three and a half feet of black shale outcropping above the limestone:

Chonetes lepidus a, *Lingula spatulata* a, *Styliola fissurella* a.

The limestone immediately below the shale yielded the following species:

Atrypa reticularis r, *Chonetes arcuatus* a, *Cyrtina hamiltonensis?* r, *Productella subaculeata* var. *cataracta* c, *Schizophoria striatulata* c, *Spirifer byrnesi* c, *Spirifer granuliferus* r, *Spirifer grieri?*, *Spirifer iowensis* c, *Stropheodonta demissa*, *Stropheodonta hemispherica*, *Stropheodonta perplana* c, *Cladopora* sp. a, *Onychodus sigmoides* r.

The limestone here does not differ lithologically from the Jeffersonville limestone as it usually appears. We have, however, an essentially Hamilton fauna if we except Chonetes arcuatus which is a Corniferous species.

At the Graham Creek ford, one and one-half miles east of Paris Crossing, the Jeffersonville limestone constitutes the upper 20 or 25 feet of the bluffs. The lower parts of these beds contain an abundance of corals with but few other fossils. The limestone at the top of the bluff contains the *Spirifer acuminatus* fauna with the following species:

Spirifer acuminatus a, *Atrypa reticularis* c, *Chonetes arcuatus* a, *Chonetes pusillis* c, *Glyptodesma occidentale*, *Orthis iowensis* c, *Onychodus sigmoides* c, *Camarotoechia tethys* c, *Spirifer iowensis* c, *Stropheodonta demissa* c, *Tentaculites bellulus?* c.

On the west side of the middle fork of Big Creek at Lancaster the following section is exposed:

	Ft.	In.
1. Gray limestone with chert bands	..	10
2. Coralline limestone	15	..
3. Buff to brownish magnesian limestone (Geneva limestone)	18	..
4. Gray limestone	5	..

No. 1 of this section is the source of the loose masses of fossiliferous chert which are abundantly scattered about the surface here.

The Coralline limestone, No. 2, is composed almost entirely of fossil corals.

The following species were obtained from No. 1 on the bank of the creek just above the bridge:

Atrypa aspera r, *Atrypa reticularis* a, *Glyptodesma occidentale* r, *Onychodus sigmoides* c, *Schizophoria striatula* a, *Phacops rana?*, *Pleurodictum problematicum* c. *Pterinea flabellum?* r, *Camarotoechia tethys* r, *Spirifer acuminatus* a, *Spirifer davisi*, *Spirifer fornaculus* r. *Spirifer varicosus* c, *Streptorhynchus* sp r, *Stropheodonta concava* r, *Stropheodonta hemispherica*, *Tentaculites scalariformis* r.

The loose masses of chert on Mr. Geo. Ferris's land a short distance north of the last section afforded the following species:

Actinopteria boydi r, *Bucania devonica* r, *Clinopistha subnasuta* r, *Cyclonema cancellatum* r, *Glyptodesma erectum* r, *Glyptodesma occidentale* a, *Schizophoria propinqua?* r, *Platyceras erectum* r, *Platyostoma lineatum* r, *Pleurotomaria sulcomarginata* r, *Camarotoechia tethys* r, *Spirifer acuminatus* a, *Spirifer euruteines* a, *Spirifer varicosus* r, *Streptorhynchus arctostriata* r, *Stropheodonta concava* c, *Stropheodonta demissa* a, *Stropheodonta hemispherica* c, *Stropheodonta perplana* c.

About one mile west of Wirt loose blocks of very hard dark brown sandstone, resembling quartzite somewhat in texture and hardness are common. This sandstone has not been found in place in this locality. In its manner of occurrence and fossils it is similar to the sandstone blocks previously referred to which occur in the vicinity of Smyrna church in Jefferson County. They represent apparently the remnants of a bed of sandstone of local development like the buhrstone on Wyloosing Creek. The fossils indicate that the Jefferson County sandstone erratics come either from the Jeffersonville limestone or the Geneva limestone.

At Kent, near the head of one of the tributaries of Big Creek is the following section:

1.	Clay and chert	4 feet.
2.	Limestone full of brachiopods	5 feet.
3.	Coralline limestone	10 feet.
4.	Dark buff impure magnesian limestone	6 feet.

The masses of chert weathered out of the limestone, No. 2 of the above section, are very rich in fossils. The following species were collected from the chert northwest of town, near the old saw mill:

Bellerophon sp., *Bucania devonica* r, *Callonema bellatulum* r, *Crania doria* r, *Cyrtina hamiltonensis* c, *Glyptodesma occidentale* c, *Loxonema hydraulicum*, *Schizophoria striatula* a, *Rhipidomella vanuxemi* a, *Paleoneilo* sp., *Platyceras buculentum* r, *Platyceras erectum* c, *Platyostoma lineatum* var. *callosum* r, *Productella subaculeata* var. *cataracta* r, *Proetus crassimarginatus*, *Camarotoechia tethys* r, *Spirifer acuminatus* c, *Spirifer arctisegmentus*, *Spirifer varicosus* r, *Streptorhynchus arctistriatus* r, *Stropheodonta demissa* a, *Stropheodonta hemispherica* c, *Stropheodonta perplana* a.

At Dupont, just above the railroad bridge the Jeffersonville limestone outcrops, showing four or five feet of buffish gray fossiliferous rock. Loose chert fragments are extremely abundant along the stream above town.

At the railroad bridge over Big Creek south of Dupont the following section is seen on the south bank of the creek:

1.	Surface clay	10 feet.
2.	Gray limestone with numerous corals (Jeffersonville limestone)	4 feet.
3.	Buff to chocolate colored magnesian limestone (Geneva limestone)	5 feet.
4.	Bluish clay and partly covered (Waldron shale)	5 feet.
5.	Hard gray limestone in strata 8 to 15 inches thick (Niagara)	15 feet.

Vernon and North Vernon sections.—The deeply cut channel of Muscatatuck Creek affords good sections of the rocks from the New Albany shale down to the Niagara limestone in the vicinity of Vernon.

Northwest of the J., M. & I. station, about 50 yards, the following section is exposed in the bank of the creek:

		Ft.	*In.*
1.	Surface clay	5	..
2.	Black fissile shale	15	..
3.	Gray to bluish shelly fossiliferous limestone	..	10
4.	Gray to bluish crystalline limestone	5	..
5.	Light gray to ash colored limestone full of calcite crystals (no fossils)	6	..
6.	Dark buff to chocolate colored massive magnesian limestone	20	..
7.	Covered	8	..
8.	Blue clay shale (Waldron shale)	..	10
9.	Gray even bedded limestone	5	..

No. 2 of this section—the New Albany shale—contains an abundance of *Chonetes lepida* and *Styliola fissurella.*

The limestone, Nos. 1 and 2 of this section, contain the following fauna:

Productella spinulicosta a, *Delthyris sculptilis* c, *Spirifer macra?* r, *Stropheodonta cancava* r, *Stropheodonta perplana* c, *Atrypa reticularis* r, *Spirifer divaricata* r, *Centronella glansfagea* r, *Schizophora striatula* r, *Reticularia fimbriata* r, *Centronella ovata ?*, r, *Cyrtina hamiltonensis*, *Phacops bufo* a, *Platyceras dumosum* r, *Platyceras sp.*, *Strophostylus varians* r, *Chonetes coronatus?* r,

It should be noted in connection with this fauna that *Spirifer acuminatus* and *Spirifer granulosus,* two species which, further south, are limited respectively to the Jeffersonville limestone and the Sellersburg beds, are absent. The species present are, for the most

part, species which occur in both the Hamilton and Corniferous faunas. The upper six feet of this section is apparently the only part of the Devonian limestone which is fossiliferous.

The 12 feet of limestone, Nos. 3, 4 and 5 of the section, represent here the Sellersburg beds and the Jeffersonville limestone. At the lower end of the tunnel Mr. Foerste has given in his report* a section in which he records "40 feet of Upper Niagara limestone, most of it dolomitic and of a light brown color,"† above the Waldron shale. I am not able to concur with Mr. Foerste in assigning 40 feet of limestone above the Waldron shale to the Niagara in the Vernon sections. The covered portion of the above section is well exposed in the vertical cliff at the north end of the tunnel leading to the Tunnel Mill. The section is as follows:

		Ft.	In.
1.	Massive chocolate colored dolomitic limestone....	14	..
2.	Hard gray limestone..........................	10	..
3.	Blue shelly calcareous sandstone................	3	..
4.	Blue sandy shale full of Niagara fossils.........	4	6
5.	Blue to gray limestone.........................	4	..

The abundance of characteristic fossils and the lithological features make 3 and 4 of this section typical representatives of the Waldron shale. As in the case of similar sections elsewhere, no fossils have been found in limestone immediately overlying the Waldron shale, No. 2 of the last section, but it is believed to belong to the Niagara, and to be the representative of the Louisville limestone. Fossils are extremely scarce in the buff or brownish dolomitic limestone, No. 1 of this section, but a few have been found in it just above the wagon bridge east of Vernon. Their poor condition does not permit of satisfactory specific determination. They have been referred to *Rhipidomella* sp. and *Proetus curvimarginatus?*. While the specific determination of the trilobite is doubtful, it appears pretty certain that it is a Devonian form. The principal reason, however, for considering the brownish buff dolomitic limestone about Vernon to be of Devonian age, is the stratigraphic evidence of its identity with the Geneva limestone. The following section taken above Geneva on Flat Rock Creek is introduced here for comparison with the sections just given:

		Ft.	In.
1.	Massive buff to brownish dolomitic limestone (Geneva limestone)	5	6
2.	Hard gray limestone in strata 3 to 8 inches thick.	6	..
3.	Waldron shale..................................	4	..

*21st Ann. Rep. Ind. Dep. Geol. and Nat. Res., 1897, pp. 213-298.
†21st Ann. Rep. Ind. Dept. Geol. and Nat. Res., 1897, p. 284.

A comparison of this seccion with the two Vernon sections which have been given, shows that the brownish buff dolomitic limestone in the latter corresponds entirely in stratigraphic position and lithological features with the Geneva limestone at the type locality which is known to be of Devonian age.

Mr. Foerste gives, in a paper published in 1897* an interpretation of the Tunnel Mill section at Vernon, differing from that expressed in his earlier report, and corresponding somewhat more closely with that of the writer. In this he refers to the Devonian everything in the Tunnel Mill section above the Waldron shale except 58 inches of limestone immediately above it, which he considers "of uncertain age."

On the north bank of the Muscatatuck, one and a quarter miles above North Vernon the following section was taken at a small quarry:

1.	Black shale	6 feet.
2.	Bluish limestone	10 feet.
3.	Light buff closely banded limestone with thin black carbonaceous partings	15 feet.
4.	Dark brownish massive saccharoidal magnesian limestone	15 feet.

The Waldron shale horizon is below drainage level at this point. Mr. Foerste recognizes it doubtfully in the section near the water wórks.

No. 4 of this section is the Geneva limestone. It is here nearly barren of fossils. One brachiopod is doubtfully referred to *Cyrtina hamiltonensis.*

As pointed out in other sections, the Devonian limestones above the Geneva limestone have lost the physical characteristics which distinguish them further south. No. 4 of the above section is probably in part the stratigraphic equivalent of the Jeffersonville limestone. The beds below No. 3, however, contain, with the exception of corals, almost no fossils. *Spirifer acuminatus*, which further south is not known above the Jeffersonville limestone, occurs here abundantly in the upper 10 feet of limestone, No. 2 of the section. Near the water works station, the same species has been found within two feet of the base of the New Albany shale. We find here a distinct mingling of the faunas of the *Spirifer acuminatus* and the *Sp. granulosus* zones.

The limestones Nos. 3 and 4 of this section were formerly extensively quarried at North Vernon. They are used at present only for crushed roçk in road building.

*22d Ann. Rep. Ind. Dept. Geol. and Nat. Res., pp. 236–237.

The limestone in the quarry northeast of North Vernon shows locally bands of black shale one-quarter to three-quarters of an inch thick in the limestone six or eight feet below the base of the New Albany shale.

Sand Creek sections.—Sand Creek crosses the northwestern part of Jennings County, cutting the Devonian formations nearly at right angles to their strike. These sections are about 60 miles north of the Falls of the Ohio.

At Helt's mill, which is about three miles below Scipio, the lower beds of the New Albany shale are exposed in the mill race and in the south bank of the creek just above the dam. The latter outcrop contains an abundance of fossils which, however, are accessible only while the dam is out of repair. The following species occur here:

Chonetes lepida a, *Leiorhynchus limitaris* a, *Tentaculites fissurella* a, *Cardiopsis* sp.

Just below the dam a hard bluish black limestone outcrops below the black shale.

Above Helt's mill three-quarters of a mile, at an old quarry, the following fossils were obtained:

Spirifer acuminatus a, *Stropheodonta demissa*, *Stropheodonta perplana*, *Tentaculites bellulus?*, *Onychodus sigmoides?*, *Pleurodyctum problematicum*, *Polyphora* sp., *Proetus canaliculatus?*.

At Scipio the New Albany shale outcrops just southwest of the Episcopal church, at the roadside. *Styliola fissurella* occurs here in great abundance. A few yards to the southwest from this outcrop the following fossils were collected from the limestone five or six feet below the black shale:

Spirifer acuminatus, *Chonetes yandellanus*, *Spirifer varicosus*, *Stropheodonta perplana*, *Stropheodonta demissa*, *Tentaculites bellulus?*, *Dalmanites* sp., *Glyptodesma erectum*.

We have here another interesting example of the mingling of the *Spirifer acuminatus* and the *Spirifer granulosus* faunas. *Chonetes yandellanus* is here associated with *Spirifer acuminatus*, while in Clark County it is one of the most characteristic species of the *Spirifer granulosus* fauna and is never found associated with *Sp. acuminatus*.

Above Scipio the Geneva limestone affords the principal outcrops along Sand Creek. About a mile and a quarter below Brewersville a small natural bridge has been developed in this limestone on the north bank of the creek across the mouth of a small ravine.

Just below the cemetery, on Wyloosing Creek, a small cave occurs in the same formation. The following section occurs at this locality:

		Ft.	In.
1.	Light buff colored limestone	8	..
2.	Very hard flinty gray limestone with numerous corals which locally pass into a nearly pure chert or buhrstone	..	26
3.	Buff chocolate colored massive saccharoidal magnesian limestone	20	..
4.	Hard blue thin bedded limestone	5	..

All of this section above 5 is referred to the Geneva limestones. No. 5 is the representative of the Niagara.

The following fauna was obtained from the Buhrstone, No. 3 of the section:

Conocardium trigonale c, *Schizodus* sp. r, *Megambonia* sp. c, *Panenca potens* c, *Pentamarella arata?* r, *Reticularia undifera?* c, *Martinia subumbona?* r, *Stropheodonta plicata* r, *Pleurotomaria* sp. c, *Strophostylus* sp. r, *Macrocheilus* sp. r, *Macrocheilus hebe?* r, *Bellerophon* sp. r, *Platyostoma pleurotoma?* r, *Naticopsis* sp. r, *Loxonema* sp. r, *Murchisonia desiderata?* r, *Orthoceras* sp.

This bed contains, in addition to the above, a rich coral fauna. All of the fossils here are in the condition of casts and usually in a very poor state of preservation.

A considerable number of millstones were manufactured from this bed at one time. It has not been worked for this purpose for more than 50 years. During the early pioneer days, millstones are said to have been obtained from this locality for mills as far west as Vincennes.

Southeast of Westport, on Millstone Branch, the same bed is well developed and makes a good buhrstone. Millstones were also cut out at this locality 75 or 80 years ago.

Along the creek road west of Brewersville the dark colored Geneva limestone outcrops in numerous vertical ledges and isolated masses with vertical weatherworn faces.

At the Big Four bridge at Brewersville the Waldron shale is seen in the following section:

1.	Blue sandy shale	5 feet.
2.	Gray and blue limestone	18 feet.

Bartholomew County sections.—East of Burnsville one-quarter of a mile the following section is exposed at the side of the road and in the bank of the stream:

	Ft.	In.
1. Drift clay	4	..
2. Black shale	2	..
3. Red clay and limestone pebbles	..	3
4. Blue to gray limestone	3	6
5. Gray limestone	4	..
6. Dark blue magnesian limestone	6	..

Spirifer acuminatus is abundant here in No. 4, within three or four feet of the New Albany shale. The beds 3 and 4 together represent here the Sellersburg beds and the Jeffersonville limestone. No. 6 is the Geneva limestone.

West of Brewersville in the southwest quarter of section 6, at the J. M. Manley limekiln, the limestone above the Geneva limestone is thicker than in the above section and is burned for lime. On the north side of the creek at Burnsville the decay of the upper Devonian limestone has left an abundance of chert rich in fossils. The section exposed here is:

	Ft.	In.
Drift clay with chert	4	6
Grayish buff dolomitic limestone with numerous small calcite veins (Geneva limestone)	10	..

The most important outcrops in Bartholomew County are along the banks of Clifty Creek and the streams entering it. The limestone is so lightly covered with drift between Duck and Clifty creeks that sinkholes are common in a part of this area to the northwest of Newbern.

In the southeast quarter of section 6 (9 north, 7 east), the New Albany shale outcrops at the roadside northeast of the schoolhouse. *Styliola fissurella* is present here in great abundance.

In the southwest quarter of section 5 (9 north, 7 east), is located the old Everrard quarry on John Burney's land. Four or five feet of bluish gray limestone are exposed here, containing an abundant brachiopod fauna. The limestone here represents the highest part of the Devonian limestone of this region.

One mile west of Newbern and about 200 yards north of the bridge, a bed of chert is exposed to the east of the road. The chert here contains an abundance of Devonian fossils.

The Geneva limestone outcrops in the bed of the creek near this point and dips below drainage a short distance below the bridge.

East of Newbern the Geneva limestone outcrops in bold ledges of massive buff to chocolate brown magnesian limestone. Fossils are extremely rare in this formation. The following were obtained from it east of Newbern about a mile and a half, from outcrops at the roadside:

Conocardium trigonale, *Proetus* sp., *Atrypa reticularis*, *Atrypa aspera* and *Streptorhynchus chemungensis arctostriatus*. The last is a distinctly Devonian species and is alone sufficient to establish the Devonian age of this formation.

At Anderson Falls, two miles south of Hartsville, the following section is exposed:

	Ft.	*In.*
1. Dark buff magnesian limestone with Atrypa reticularis and a few corals (Geneva limestone)..	9	..
2. Hard arenaceous gray limestone without fossils (Louisville limestone?)	4	6
3. Blue calcareous and arenaceous shale with Waldron fossils (Waldron shale)	5	6

No. 2 of this section Mr. Foerste considered of uncertain age.*

Mr. Price in his report on the Waldron shale calls it the "Hartsville ledge."† It appears to the writer to be the stratigraphic equivalent of Foerste's Louisville limestone.

Between the forks of Clifty Creek and Hartsville the Geneva limestone shows many prominent outcrops, frequently presenting a ledge of dark brownish buff sandy looking limestone with vertical face 8 to 20 feet high. The Waldron shale outcrops from four to six feet below it at many points and affords an abundance of fossils (see Price's report).‡

Just north of Hope, in the bed of Haw Creek, a soft buff sandy looking dolomitic limestone outcrops. About 150 yards east of the road this stone has been quarried for local use. The outcrops in the quarry and creek together show about eight feet of stone.

Northwest of Hope, near the junction of Tough and Haw creeks, a small quarry has been worked for road metal. The rock is a shelly impure limestone and apparently belongs, together with the above mentioned outcrops, to the Geneva limestone.

Fossils are comparatively scarce in this limestone, and are limited mainly to *Conocardiums*, *Gasteropods* and a new species of *Martinia*.

Johnson County.—The northernmost outcrop of the New Albany shale in the southern Indiana area occurs in the bank of Sugar

*22d Rep. Ind. Dep. Geol. and Nat. Res., p. 241.
†24th Ann. Rep. Ind. Dep. Geol. and Nát. Res., p. 125.
‡24th Ann. Rep. Ind. Dep. Geol. and Nat. Res., pp. 81–143.

Creek about 100 yards below the Pennsylvania railroad bridge. Nine or 10 feet of fissile black shale is exposed in the bank of the creek overlaid by drift. Mr. Wm. Neal's well, which is a few rods from this outcrop, has penetrated the shale to a depth of 40 feet without passing through it, so that the shale at this point has a thickness of a least 45 feet.

Just below the mill-dam at Edinburg loose pieces of black shale are thrown up on a gravel bar but the outcrop is in the bed of the river and is not accessible. The Devonian limestone does not outcrop in the county.

Flat Rock sections.—The sections exposed along this stream are about 85 miles north of the Falls of the Ohio, and are the northernmost outcrops of the Devonian limestone in the southern Indiana area. Flat Rock Creek and its tributary, Conn's Creek, cut through the Devonian and Niagara limestones in the southeastern part of Shelby County, exposing beds as low as the Laurel limestone. The New Albany shale is not exposed in these sections, but outcrops nearly west of them at the Johnson County localities previously mentioned.

The following section, taken one and a quarter miles above Geneva on the west bank of Flat Rock Creek, indicates the relations of the beds exposed in the vicinity of Geneva:

	Ft.	*In.*
1. Brownish buff dolomitic limestone with saccharoidal texture	5	6
2. Hard gray limestone in 3 to 8 inch courses	6	..
3. Waldron clay partly covered	4	..

No. 1 represents the lower part of the limestone which Collett called the Geneva limestone. Prof. Collett's original section at Geneva is as follows:*

Slope and soil, buff magnesian limestone for calcining, Devonian	28 feet.
Stratified rubble stone, cap of fossiliferous blue shale to same in river	4 feet.
Total	32 feet.

Collett considered the Geneva limestone of Devonian age, but did not offer any proof of his opinion.

Fossils are generally very scarce and poorly preserved in this formation. One locality has been found, however, where gasteropods are fairly abundant. The following fauna was secured at this lo-

*11th Ann. Rep. Ind. Dep. Geol. and Nat. Hist., 1881, p. 82.

PLATE 15.

a

b

(a) View of Jeffersonville limestone near Bunker Hill, Miami County, Indiana.
(b) View of Sellersburg beds near Delphi, Carroll County, Indiana.

cality, which is located on the north bank of the creek about three-quarters of a mile above Cave Mills and below the Park a short distance:

Atrypa reticularis, *Orthothetes chemungensis arctostriatus*, *Cyrtina hamiltonensis*, *Stropheodonta perplana*, *Delthyris raricosta*, *Pentamarella arata*, *Ambocaellia umbonata*, *Martinia subumbona*, *Eunella* sp , *Stropheodonta demissa ?*, *Spathella typica ?*, *Conocardium trigonale*, *Proetus* sp., *Pleurotomaria filatexta ?*, *Pleurotomaria* sp., *Polyphemopsis louisvillæ*, *Orthoceras crotalium ?*, *Cyrtoceras morsum ?*, *Gomphoceras raphanus ?*, *Gomphoceras* sp., *Zaphrentis* sp.

This is a distinctly Devonian fauna and places the age of the Geneva limestone beyond question.

A slight unconformity exists between the Geneva limestone and the hard grayish limestone immediately below it. An outcrop on the east side of Flat Rock Creek at the ford about one and one-third miles above Geneva shows this unconformity. The section exposed at this point is:

	Ft.	*In.*
1. Brownish dolomitic saccharoidal limestone (Geneva limestone)	3	..
2. Hard light gray limestone	5	6
3. Blue fossiliferous clay with irregular masses of limestone (Waldron shale)	5	..
4. Hard gray limestone	..	15

The character of the unconformity between 1 and 2 is shown in the accompanying photographs. The bed on which the hammer rests is No. 2 of the above section.

This unconformity is also seen in the Wm. Avery quarry on the east side of Conn's Creek about one mile below Waldron, where the following section is exposed:

	Ft.	*In.*
1. Brownish buff sandy looking limestone	2	6
2. Clay	..	1
3. Blue limestone in 3 to 6 inch layers	5	6

The thin clay band marks the line of unconformity in this section. The bed No. 1 (Geneva limestone) lies horizontal, while the limestone No. 3 dips three or four degrees to the northwest. A hard sandy shale about 15 inches below the floor of the quarry represents the Waldron shale.

The specimens from which Prof. Hall's descriptions of the Waldron fossils were made were obtained nearly due west of this quarry along the creek. No fossils have been found in the limestone be-

tween the Waldron shale and the Geneva limestone. The lithological differences which everywhere distinguish the Geneva limestone from the beds below, together with the unconformity between the two in the Flat Rock sections, leads the writer to consider this limestone to belong to the Niagara, and to represent, as suggested by Mr. Foerste in his report,* the Louisville limestone.

The general westerly dip of the rocks carries the Louisville limestone below drainage level at Geneva. The Geneva limestone has been burned for lime at Geneva for a number of years. About 19 feet of limestone is exposed in the lime quarry. It is a dirty buff to brownish limestone in strata three inches to three feet thick.

Extensive outcrops of the Geneva limestone occur on both sides of the creek near Cave Mill. A small cave occurs in the limestone at the south end of the dam. About half a mile further up stream a larger cave is found on the north side of the stream. Just below the bridge at Cave Mill about 15 feet of the Geneva limestone is exposed which is here a dull buff to drab colored magnesian limestone. Frequent outcrops of this formation are seen as far down as the ford one mile west of Flat Rock P. O.

The Sellersburg beds and Jeffersonville limestone, if present, in the Flat Rock region, do not outcrop. Their absence in the sections exposed makes it probable that they have thinned out and are represented entirely by the Geneva limestone.

THE PENDLETON AREA.

The town of Pendleton is located about twenty-eight miles northeast of Indianapolis, and forty-two miles north of the northernmost sections of the southern Indiana area. The territory which is here designated as the Pendleton area includes a very limited district in the southern part of Madison County in the immediate vicinity of Pendleton. All of the Devonian outcrops occurring near the central part of the State are found, so far as known, in this limited area. Extensive outcrops of rocks of Niagara age or older occur to the north of it in the central part of Madison County along White River.

In Henry County, which lies east of Madison, the only Paleozoic outcrop known was found to contain Niagara fossils.

South of Pendleton no bed rock outcrops for more than forty miles.

West of Pendleton, in Hamilton County, outcrops of bed rock occur at a number of places, the most extensive being those at Con-

*22d Ann. Rep. Ind. Dep. Geol. and Nat. Res., pp. 234-235.

nor's mill on White River. In Dr. R. T. Brown's report on Hamilton County, he states that "the outcrops of rock in Hamilton County are quite barren of fossils."* The outcrop at Connor's mill was considered by Dr. Brown to be of Devonian age. The writer has secured a rich Niagara fauna from this limestone which will be described in a future paper. The "Corniferous limestone" of Brown along Stony Creek in Hamilton County has also been found to contain a Niagara fauna. It overlies unconformably a sandstone in which no fossils were found.

The Pendleton section.—Prof. E. T. Cox published, in 1879, the following section of the rocks at Pendleton:†

1. Drift with large boulders of granite and other crystalline rocks strewed over the surface........... 50 feet.
2. Ash colored rough weathering, cherty magnesian limestone, alternating with soft sandy, greenish colored, pyritous layers, in all about............ 4 feet.
3. Buff sandy magnesian limestone, Pleurotomaria and coral bed .... 4 feet.
4. Heavy bedded and soft, white sandstone, upper part fossiliferous .... 15 feet.

The above is evidently a connected section since No. 2 has not been found anywhere resting directly on No. 3 at Pendleton. The magnesian limestone No. 2, however, occurs at a little greater absolute elevation than the sandstone in the outcrops of the two which are not very distant from each other, and this doubtless led Professor Cox into the error of supposing that No. 2 is a bed of later formation than No. 3. Both of these he referred to the Corniferous epoch on the evidence of fossils from the sandstone bed No. 3. The writer has found in the ash colored limestone No. 2 a Niagara fauna in which *Sphærexochus romingeri* is one of the most common species. The fauna of the sandstone is of Devonian age, so that the order of the beds as given by Cox presents the strata in reverse order, the oldest at the top. Whether the apparent order of the beds which has led to their misinterpretation in Professor Cox's section is due to a fault, to unconformity or to some other cause, the few outcrops and the limited time spent on the stratigraphy of the region has not permitted the writer to decide. The ash or buff Niagara limestone referred to above has few outcrops and may be best seen in the cellar of a house standing on a small knoll 100 yards south of Fall Creek on Charles Clarke's lot.

*14th Ann. Rep. Ind. Dept. Geol. and Nat. Hist., 1884, p. 27.
†8th, 9th and 10th Ann. Reps. Geol. Surv. Ind., 1879, p. 60.

Both Cox and Brown, in their reports on the geology of this locality, appear to have overlooked an interesting conglomerate formation whose remnants are very abundant in some parts of the town of Pendleton. This conglomerate is a matrix of coarse sand and well rounded chert pebbles, which are frequently three or four inches in diameter. The pebbles often constitute nearly the whole of the rock. This bed, where observed, is from 4 to 12 inches thick. In the orchard lot of Mr. Chas. Clarke, near the Universalist church, the loose slabs of the conglomerate were so large and numerous as to interfere seriously with the planting of trees. The same formation is conspicuous in some open lots on the south side of town about 100 yards east of the railroad. At the top of a little knoll in that vicinity near an old limestone quarry the loose pièces of conglomerate are numerous. On the north side of Fall Creek, just east of Main Street, the conglomerate may be seen in place. It outcrops also on the opposite side of the street at the east end of a small knoll. The exposures here show the conglomerate to be a bed of local development in the upper part of the Pendleton sandstone. There is no trace of the bed in the sandstone quarry three or four hundred yards to the southeast of the above mentioned locality.

The best exposures of the rocks at Pendleton are found at the Fall just below the Big Four railroad bridge, and at the quarry southwest of the latter, where the formation named the Pendleton sandstone by Professor Cox* is quarried.

The following section was taken at the quarry and in the bank of the creek:

		Ft.	In.
1.	Hard gray limestone	3	6
2.	Massive white sandstone with 10 to 12 inch strata.	6	8
3.	Bluish drab calcareous fine grained sandstone....		10+

The following fossils were found in bed No. 1: *Reticularia fimbriata* c, *Eunella* sp. r, *Martinia subumbona* r, *Pleurotomaria* sp. c

In the sandstone No 2 the following fauna occurs: *Reticularia fimbriata* var. a, *Martinia subumbona* c, *Eunella* sp r, *Pentamarella arata* r, *Atrypa reticularis* r, *Tentaculites dexithea* c, *Bellerophon curvilineatus* r, *Callonema bellatula*, *Schizodus contractus* (?) c, *Conocardium trigonale* c, *Conocardium cuneus* c, *Proetus curvimarginatus* c, *Proetus latimarginatus* c, *Cyrtoceras eugenium* r, *Zaphrentis giganteum* r, *Favosites limitaris* c.

The above list adds some species to those recognized by Hall from this section, but does not materially alter the evidence on which he

* Rept. Geol. Surv. of Ind., 1876–1878, pp. 60–62.

corellated the Pendleton sandstone with the Schoharie Grit of New York.*

The presence of Niagara fossils in the bed immediately below the Pendleton sandstone still further strengthens the view that the Pendleton sandstone fauna represents the Eodevonian fauna.

The following species occur below the sandstone in No. 3 of the section: *Dalmanites verrucosus*, *Leptæna rhomboidalis*, *Cornulites proprius?*, *Murchisonia* sp., *Schizotreta tenuilamellata?*, *Euomphalus* sp , *Orthoceras* sp , *Streptelasma*(?) sp.

Bed No. 1 of the section outcrops at a few points along the creek between Pendleton and Huntsville and is frequently a sandy dirty buff rock containing casts of a large gasteropod. This is the "*Pleurotomaria* and coral bed" of Cox's section.

The limestone outcrops near Fall Creek below Pendleton are all, so far as examined, of Niagara age. About four miles southwest of Pendleton the Niagara limestone is extensively quarried for lime.

THE WABASH AREA.

In many places along the Wabash River and the streams joining it in northern Indiana, the drift is thin, and outcrops of the Devonian and Niagara are correspondingly numerous. The outcrops of the Devonian, so far as known, are confined to that portion of the Wabash Valley between Peru and Delphi and to the Tippecanoe River near Monticello.

STRATIGRAPHY.

The New Albany shale outcrops extensively in the vicinity of Delphi, along Rock Creek, and above Monticello on the Tippecanoe. The bulk of this formation is composed of fissile black shale identical in appearance with that of the same formation in southern Indiana. Interstratified with the black shale are beds of arenaceous or argillaceous drab gray colored shale of varying thickness which are unlike anything occurring in the southern Indiana sections. These drab colored beds carry a fauna which has not been recognized elsewhere, and which will be described in another section of this paper. None of the sections observed show the upper limit of the New Albany shale in this region. It appears from well sections, however, that the Rockford limestone is absent in this area.

The Devonian limestones of the Wabash area are differentiated both faunally and lithologically into two divisions, as in the southern

*8th to 10th Ann. Reps. Ind. Geol. Surv., 1879, p. 60.

part of the southern Indiana area. These two divisions are correlated respectively with the Sellersburg beds and the Jeffersonville limestone. The Sellersburg beds of the Wabash area contain a Hamilton fauna, but the predominant species in it are forms which are unknown in the Sellersburg beds of southern Indiana. *Spirifer pennatus* is the most abundant and generally distributed species, and the fauna may be called the *Spirifer pennatus* zone of the Wabash area. *Spirifer granulosus*, which is so characteristic of the Sellersburg beds where typically developed in the southern part of the State, has not been observed in the rocks of the Wabash area.

The beds lying immediately below the New Albany shale and holding the *Spirifer pennatus* fauna are composed of a limestone darker in color and more impure than the limestone below them. This limestone varies from a fairly pure bluish drab rock, breaking with subconchoidal fracture to a very dark arenaceous limestone. At the only place where the entire thickness of this bed could be observed it did not exceed 14 feet.

The formation corresponding to the Jeffersonville limestone at the Falls of the Ohio is a gray crystalline, thin to heavy bedded limestone. This limestone carries a fauna similar to that of the same formation in southern Indiana, and has, as one of its most characteristic species, *Spirifer acuminatus*. This limestone is unconformable with the Niagara on which it rests, over a part of the area at least. The Niagara rocks at many points are highly tilted, while the Devonian beds lie nearly horizontal.

SECTIONS.

White County.—The New Albany shale and the Sellersburg beds outcrop along the Tippecanoe River, about two miles above Monticello, near the old mill-dam. The New Albany shale outcrops on both sides of the river about a quarter of a mile above the dam. The following section occurs on the west side of the river about one-quarter of a mile above the dam:

	Ft.	*In.*
Surface clay	4	..
Black shale	5	..
Blue clay shale band	..	½
Black shale	5	..
Blue shale	..	1½
Black shale	..	8
Blue clay	..	2
Black shale	7	..

On the east bank of the river the shale shows a slight dip to the west and north.

PLATE 16.

a

b

Views showing unconformity between Genesee limestone and Niagara limestone, Flat Rock Creek, Shelby County, Indiana.

The Sellersburg beds outcrop in the bed of the river at the dam and in the old mill race just east of the dam. About two feet of dark gray to almost black arenaceous limestone is exposed here. The cavities left in it by fossils often contain asphaltum. The following fauna was obtained here, and from the same beds at the side of a small branch entering the river from the northeast at this point:

Spirifer pennatus **c. *Stropheodonta plicata* a, *Atrypa reticularis* c, *Cyrtina hamiltonensis* r, *Spirifer* sp , *Zaphrentis* sp., *Cyathophyllum* sp.**

The above described outcrops comprise the only exposures of Devonian rocks known to occur in White County.

Delphi.—The New Albany shale outcrops extensively along Deer Creek near Delphi. From the Wabash railroad bridge over Deer Creek to its mouth the shale forms a nearly continuous outcrop, showing a thickness of about 30 feet in the section exposed.

About three-quarters of a mile east of Delphi and just west of the crossing of the Monon Railway and the Camden pike the New Albany shale outcrops at the side of the road. The section exposed is as follows:

1.	Black shale	12 feet.
2.	Blue clay shale	4 feet.

The clay shale No. 2 contains a rich fauna which has not been seen elsewhere. Nearly all of the fossils are partially or entirely pyritized. The position of this bed with reference to the base of the New Albany shale can not be stated precisely, since the nearest outcrops of the underlying Devonian limestone are some two or three hundred yards distant. They are, however, probably within twenty feet of the base of the shale. The following is a list of the species occurring here:

Palaeoneilo **sp., *Goniatites wabashensis* n sp., *Goniatites delphiensis* n. sp., *Orthoceras* sp , *Plethospira socialis ?* *Pleurotomaria* sp., *Macrochilina ?* sp.**

On the opposite side of Deer Creek from this section and about 200 yards above the old mill-dam the following section is exposed:

		Ft.	*In.*
1.	Drift	7	..
2.	Bluish black shale, sheety and tough	45	..
3.	Drab grayish colored slightly sandy shale	4	6
4.	Band of gray colored concretions	..	6 to 14
5.	Drab colored sandy shale	10	6
6.	Bluish gray sandstone	4	10
7.	Drab colored sandy shale	5	6
8.	Covered	8?	..
9.	Devonian limestone	..	..

The Devonian limestone (9) outcrops at the dam about 200 yards below the remainder of the section. The thickness of No. 8 is estimated, while the remainder represents a continuous section in the nearly vertical bank of the creek.

In the black shale No. 2 of the above section only one species was found—*Lingula spatulata.*

In the drab colored shale No. 3, the following species occur: *Stropheodonta* sp., *Lingula* sp. and *Spathiocaris emersoni.* The bed containing these fossils lies at the same level as bed No. 2 of the preceding section, so that the species listed from beds 2 and 3 of these two sections constitute the same fauna.

The following section taken on the north side of Deer Creek at the south end of the old Deer Creek channel is representative of the Sellersburg limestone about Delphi:

	Ft.	*In.*
1. Drift	5	..
2. Gray clay shale	3	..
3. Black shale	..	1 to 4
4. Reddish brown ferruginous clay with some iron and concretions	..	1 to 3
5. Bluish gray limestone in regular courses 3 to 11 inches thick (Sellersburg beds)	13	6
6. Light gray limestone (Niagara?)	8	..

Bed No. 5 dips two or three degrees toward the south. *Spirifer pennatus* occurs in it, and with the exception of a *Chonetes* is the only species found in it. The Jeffersonville limestone is absent from this section. This section is shown in the upper photograph, Plate 16.

The following sections occur at a small quarry on the east side of Delphi, in the southeast quarter of section 20:

	Ft.	*In.*
1. Black shale	..	10
2. Hard dark gray limestone in strata 8 to 10 inches thick	7	..

Spirifer pennatus is quite common here, and a single specimen of *Conularia* sp. was found in the limestone. This is the only locality where this genus has been found in the Indiana Devonian.

The Devonian limestone outcrops in the bank of Deer Creek, about 150 yards southwest of the standpipe, exposing about seven feet of siliceous dark gray limestone.

Rock Creek and Little Rock Creek.—These two streams enter the Wabash from the southeast, about midway between Delphi and Ken-

neth. The New Albany shale outcrops along Rock Creek northeast of Rockfield. The shale here forms the bed of the creek, and sections 15 to 30 feet thick are exposed in the bluffs along the stream.

Little Rock Creek enters the Wabash about one mile above Lockport. Immediately above where the road crosses the stream the Lower Devonian limestone outcrops in its bed. One hundred yards further up the stream the Upper Devonian shows in the banks, but a better exposure of it may be seen at an old quarry about a quarter of a mile above the mouth of the creek and about one hundred yards to the west of it. A connected section of these outcrops gives the following:

		Ft.	*In.*
1.	Surface clay and soil	4	6
2.	Drab colored fine textured limestone, breaking with conchoidal fracture	7	..
3.	Gray crystalline limestone	1	..
4.	Buff to brown sandy limestone, some layers almost pure sandstone	2	..
5.	Gray shelly limestone	..	6 to 8
6.	Hard blue limestone	..	15
7.	Gray Niagara limestone	1	..

No. 2 carries the *Spirifer pennatus* fauna and is correlated with the Sellersburg beds.

Beds 3 to 6 carry the *Spirifer acuminatus* fauna and are correlated with the Jeffersonville limestone. The composition of the *Sp. acuminatus* fauna as represented in the different beds from 3 to 6 does not vary materially, and the following list represents the fauna of these four beds:

Spirifer acuminatus a, *Stropheodonta demissa* a, *Rhipidomella vanuxemi* c, *Stropheodonta concava* r, *Stropheodonta preplana* c, *Cyclorhina nobilis* r, *Athyris fultonensis* c, *Atrypa reticularis* c, *Spirifer iowensis* r, *Reticularia fimbriata* c, *Pentamarella arata* c, *Camarotoechia tethys* r, *Camarotoechia congregata* r, *Trematospira hirsuta* r, *Tentaculites scalariformis* r, *Pholadistrophia iowensis* r, *Productella subaculeata* c, *Streptorhynchus chemungensis arctostriatus*, *Eunella harmonia* r, *Stropheodonta inequistriata* a, *Cyrtina hamiltonensis* r, *Platyceras thetis* a, *Platyceras buculentum* a, *Platyceras ventricosum* r, *Platyceras fluctuosum* c, *Platyceras indianensis* c, *Platyceras blatchleyi* n. sp. r, *Dalmanites boothi* a, *Phacops rana* r, *Proetus folliceps* r, *Platyceras conicum* r, *Platyceras carinatum* c, *Turbo shumardi* r.

No. 2 furnished the following fauna:

Spirifer pennatus c, *Martinia subumbona* c, *Chonetes manitobiensis* c.

It is interesting to note that not one of these three species is known in the Devonian sections where the Sellersburg beds are typically developed near the Ohio River. They are all Upper Devonian species, however, and the beds containing them are for that reason correlated with the Sellersburg beds.

The fauna from the beds just below these is essentially the same as that which can be found in the Jeffersonville limestone at nearly any locality in southern Indiana.

Little Rock Creek to Georgetown.—The Sellersburg limestone outcrops in the road on the south side of the river at the mouth of Keep's Creek. It is here a fine grained, dark gray limestone, with *Spirifer pennatus.*

The Niagara limestone outcrops in the river below the mouth of Crooked Creek, forming the bed of the river just above Keep's Creek.

Just below Georgetown both the Niagara and the Devonian are exposed on each side of the river. From five to eight feet of gray crystalline Devonian limestone rests unconformably on the Niagara. The line of contact between the two is an irregular one, frequently rising or sagging. On the east side of the river the Niagara dips from six to 18 degrees to the east, while the Devonian limestone lies horizontal above it. The Jeffersonville limestone is the only division of the Devonian present here. *Spirifer acuminatus* is the most abundant fossil in it. About one-half mile below the Georgetown bridge the Niagara limestone dips below the bed of the river and the Devonian then forms the river bed for a short distance.

Waverly—Logansport.—No outcrops of the Devonian have been observed between Logansport and Georgetown. The extensive quarries at Kenneth are in rocks older than the Devonian.

About one mile south of the Wabash at Logansport a lime quarry is operated in Devonian limestone. The limestone outcrops frequently over about 60 acres in the vicinity of the lime kilns, and over a considerable part of this tract it is covered by a very few inches of soil and clay. The exposures here belong to the Jeffersonville limestone.

A hard gray flaggy limestone outcrops in the bed of the Wabash River above the wagon bridge at Logansport. The loss of paleontological material collected here has prevented a positive determination of their age, but they are believed to be of Niagara age.

At Keysport, about three miles above Logansport, lime is extensively manufactured from the limestone outcropping on the north bank of the Wabash. The section in the quarry is as follows:

		Ft.	In.
1.	Shelly buff limestone	4	6
2.	Hard, blue limestone with calcareous concretions	10 to 13	..
3.	Light buff limestone	..	15

No. 1 contains an abundance of Devonian fossils characteristic of the Jeffersonville limestone. Except corals, fossils are very scarce in 2 and 3 of the section. In the absence of satisfactory material for the correlation of these beds, they are provisionally referred to the Niagara.

The Devonian limestone shows frequent outcrops above Keysport, near the wagon road, as far as the upper end of Cedar Island. Cedar Island itself, however, appears to be composed entirely of Niagara rocks.

On the south side of the Wabash River, just above Cedar Island, an isolated mass of Devonian limestone forms a turret-like mass to the south of the road. Similar isolated outcrops of the Devonian occur on each side of the road about one mile west of the mouth of Pipe Creek.

South of Waverly a mile and a half, Devonian limestone outcrops in the river bluffs on the Casebeer farm. The section exposed at the roadside is as follows:

Dark gray limestone with rich Lamellibranch fauna and corals (Devonian)	4 feet.
Buff magnesian limestone (Niagara)	14 feet.

Adamsborough is the only locality at which the Devonian is known to outcrop on Eel River. The section exposed on the east bank of the river below the mill shows:

White shelly limestone full of fossils	6 feet.
Hard bluish gray limestone with few fossils	3 feet.

Pipe Creek.—This stream enters the Wabash seven miles above Logansport. A waterfall about seven feet in height occurs two miles above its mouth. Below the fall for two or three hundred yards the channel is cut for the most part in Niagara limestone; above the falls the bed of the stream is Devonian limestone for several hundred yards. The section just below the bridge at Pipe Creek Falls is as follows:

		Ft.	In.
1.	Gray limestone (Devonian)	4	6
2.	Hard buff limestone (Niagara)	14	..

The fossils of the Devonian limestone here show it to be the representative of the Jeffersonville limestone. Th following is a list of the Devonian fauna of Pipe Creek Falls:

Cryptonella ovalis a, *Cryptonella lens* c, *Rhynchonella tenuistriata* c, *Rhynchonella gainesi* c, *Trematospira hirsuta* c, *Eunella sullivanti* c, *Terrebratula romingeri* a, *Productella spinulicosta* a, *Atrypa reticularis* c, *Centronella navicella* r, *Cyrtina hamiltonensis* r, *Spirifer angusta* r, *Eunella harmonia* r, *Spirifer divaricatus* a, *Eunella lincklaeni* c, *Spirifer byrnesi* var. a, *Cyclorhina nobilis* r, *Stropheodonta inequistriata* a, *Athyris fultonensis* r, *Stropheodonta demissa* r, *Reticuluria fimbriata* a, *Aviculopecten terminalis* r, *Pentamarella arata* c, *Proetus crassimarginatus* r, *Proetus folliceps* r, *Proetus macrocephalus* c, *Actinopteria boydi* c, *Pterinopecten hermes* r, *Leptodesma* sp. r, *Platyceras erectum* c, *Platyceras crassum* r, *Platyceras indianensis* r, *Cyclonema* n. sp. r, *Euomphalus planodiscus* r, *Euomphalus decewi* r, *Camarotoechia sappho* r, *Camarotoechia tethys* c, *Spirifer fornaculus* a, *Orthothetes chemungensis arctostriatus* r, *Callonema bellatula* r, *Rhipidemella vanuxemi?* r, *Camarotoechia gregaria?* r, *Platyceras conicum* r, *Platyceras argo?* c, *Platyceras echinatum* r, *Platyostoma* sp. r, *Leptodesma rogersi* c, *Cypricardina indenta* c, *Paracyclas eliptica* c, *Aviculopecten invalidus* r, *Leiopteria* sp. r, *Avicolopecten terminalis* r, *Clinopistha exacutus* r.

About one mile above Pipe Creek Falls the Devonian limestone outcrops in the bed of the creek just below the ford. The limestone at this point is a dark blue, impure, somewhat shelly limestone, with an abundance of bryozoan corals, *Stropheodonta concava,* and *Rhipidomella vanuxem?*.

Above Pipe Creek Falls no Devonian limestone outcrops until the vicinity of Bunker Hill is reached. Near the wagon bridge three-quarters of a mile northwest of Bunker Hill the Jeffersonville limestone outcrops along the creek both above and below the bridge. Above the bridge the Jeffersonville limestone is a rough bedded gray limestone, and forms the bed and sides of the creek. See Plate 15. Below the bridge 300 yards is the following section:

1.	Shelly white limestone (Devonian)	5 feet.
2.	Dull gray to buff magnesian limestone (Niagara)...	6 feet.

The following is a list of the fauna occurring in the Devonian limestone near Bunker Hill:

Spirifer divaricatus a, *Productella spinulicosta* c, *Camarotoechia congregata?* r, *Rhynchonella gainesi* c, *Stropheodonta inequistriata* a, *Reticularia fimbriata* a, *Pentamarella arata* c, *Spirifer manni* r, *Spirifer byrnesi* r, *Cyrtina hamiltonensis* r, *Orthothetes chemungensis arctostriatus* r, *Rhynchonella tenuistriata* r, *Atrypa reticularis*, *Pterinopecten hermes* r, *Pterinopecten*

undosus r, *Aviculopecten terminalis* r, *Modiomorpha* sp. r, *Platyceras indianensis* r, *Cyclonema crenulata*, *Euomphalus* sp, *Polyphemopsis louisvillae ?*, *Proetus macrocephalus* r, *Proetus crassimarginatus* c, *Cryptonella ovalis* r, *Centronella navicella* r, *Terrebratula romingeri* c, *Cryptonella harmonia* c, *Aclisina* sp r, *Cyclonema* sp. r, *Platyostoma* sp. r, *Platyceras* sp. r, *Cryptonella lens* r, *Eunella lincklaeni* r, *Aviculopecten terminalis* r, *Pterinopecten hermes* c, *Cypricardinia indenta* r, *Discina* sp. r, *Camerotoechia tethys* r, *Cyclorhina nobilis* r, *Athyris fultonensis* r, *Trematospira hirsuta* r, *Euomphalus decewi* r, *Nucleocrinus* sp. r, *Orthoceras* sp. r, *Polyphemopsis louisvillae* r, *Callonema imitator* r, *Platyostoma* sp.

CORRELATION.

The following table indicates approximately the relations which the several Devonian formations described in the preceding pages sustain to each other:

Southern Indiana Area.	Pendleton Area.	Wabash Area.
New Albany shale	Drift covered	New Albany shale.
(S. part of area.) (N. part of area.)	?	Sellersburg beds.
Sellersburg beds ....? Jeffersonville limestone } Geneva limestone	Pendleton sandstone.	Jeffersonville limestone.

When the first attempts were made to determine the age of the New Albany shale, its known fauna was limited to one or two species of *Lingula*. Since the discovery of the Lexington fossils by Borden in 1874* the formation has been correlated with the Genesee of the New York scale. The discovery by the writer of a new fauna in the New Albany shale at Delphi throws some additional light on the difficult problem of the true position of this formation in the time scale. Associated with several species which are new or undetermined, we find in this fauna *Spathiocaris emersoni*, a well known representative of the Naples fauna of New York.

This fossil is not known in the Genesee in the New York sections, but occurs in the Portage and even as high as the Lower Chemung.†

Of the species which have been previously known in the New Albany shale at least three are characteristic Genesee species; one is common to the Portage and the Genesee. The presence in the New Albany shale of a Genesee fauna and a Portage fauna seems to justify the conclusion that this formation is the western representative of both the Genesee and the Portage.

*Geol. Surv. of Ind., 1874, pp. 112-134.
†Bull. U. S. Geol. Surv., No. 16, p. 47.

The *Styliola fissurella* fauna does not bear any stronger evidence of the Genesee age of the New Albany shale than does the *Spathiocaris emersoni* fauna of its Portage age; these two faunas, however, are not intermingled in the New Albany shale. While there is no evidence that either one occupies a higher stratigraphic horizon than the other, they are found in unlike sediments. The *Styliola fissurella* fauna is confined to the fissile black shale, while the *Spathiocaris emersoni* fauna occurs in a soft drab shale which is interbedded with the *black* shale in northern Indiana. The New Albany shale of northern Indiana contains in its fissile black strata and its drab sandy beds the lithologic elements of both the Genesee and the Portage. But neither these beds nor the elements of the Genesee and Portage faunas which they contain are sharply differentiated as they are in the eastern Devonian province.

The problem of the correlation of the Devonian limestones with the New York scale is much more difficult for some parts of the Indiana province than for others. In the vicinity of the Falls of the Ohio, we find two quite distinct and well marked faunas. These are the *Spirifer granulosus* and the *Spirifer acuminatus* faunas, and represent respectively the Hamilton and Corniferous faunas of New York. Near the Falls of the Ohio the Sellersburg beds and the Jeffersonville limestone which carry these faunas are sharply differentiated lithologically, the Jeffersonville limestone being a nearly pure limestone, and representing clear water conditions during its deposition, while the Sellersburg beds are composed of an impure argillaceous limestone. In the northern part of the southern Indiana area these two formations cease to be sharply differentiated lithologically and merge into each other in a limestone which is neither so pure as the Jeffersonville limestone nor so argillaceous as the Sellersburg beds near the Falls. Associated with the loss of individuality of these two formations occurs a mingling of their two faunas which renders them indistinguishable as separate faunas.

In the Wabash area the faunas of the Devonian limestone are even more distinct than at the Falls of the Ohio. In the lower one *Spirifer acuminatus* is an abundant fossil and the fauna does not differ greatly from that in the Jeffersonville limestone at the Falls of the Ohio. The upper fauna is a distinctly Hamilton fauna, but entirely different from the Hamilton fauna of southern Indiana. Two of the most abundant fossils in it are *Spirifer pennatus* and *Chonetes manitobiensis*. Neither of these species is known in the southern Indiana area.

PART II.—PALEONTOLOGY.

DEVONIAN BLACK SHALE FOSSILS.

BRACHIOPODA.

LEIORHYNCHUS.

A. Plications angular or subangular, nearly uniform in character, covering the entire surface of the shell. *L. limitaris.*

AA. Plications rounded, not uniform; those on sides of shell obscure and frequently becoming obsolete toward the margin. *L. quadricostata.*

Leiorhynchus quadricostatum (Vanuxem).

Pl. I. figs. 5, 5a.

L. quadricostatum Hall, Pal. N. Y., 1867, Vol. IV, p. 356, Pl. 56, figs. 44-49.

Hall's description.—"Shell broadly ovate somewhat gibbous, with distinct mesial fold and sinus. Ventral valve a little gibbous towards the beak; sides nearly flat with a wide mesial fold and sinus. Dorsal valve more gibbous than the opposite, greatest convexity in the middle of the valve; mesial fold prominent. Surface of mesial fold marked by three, four or five rounded plications which bifurcate above. Sides of the valves obscurely marked by rounded plications, which become obsolete toward the margin, and sometimes this part of the shell is entirely free from any markings whatever."

A cast of the dorsal valve shows it to possess a thin, high median septum extending a little more than one-third the length of the valve, terminating under the umbo in a rounded subovate process. The specimens present considerable variation in the number and strength of the plications.

This shell is known only at a few localities where it is very abundant.

Formation and locality.

New Albany shale; Lexington, Falls of the Ohio and Helt's Mill, Jennings County.

Leiorhynchus limitare (Vanuxem).

This species was recognized by Whitfield in a collection from Lexington. He states that "only a few individuals in the collection can with certainty be referred to this species. They are flattened on

the surfaces of the shale and resemble very closely those so common in the Marcellus shale of New York."*

Formation and locality.

New Albany shale; Lexington.

Chonetes lepidus Hall.

Pl. I, fig. 7.

C. lepidus Hall, Pal. N. Y., 1867, Vol. IV, p. 132, Pl. 21, fig. 5.

Shell very small, subhemispherical in outline. Ventral valve moderately gibbous with a well marked medial depression in which there are from one to four striae; curving abruptly to the sides and front, with cardinal angles scarcely flattened. Dorsal valve following the curvature of the opposite valve but less arched. Area of the ventral valve narrow, widest in the middle. Area of dorsal valve scarcely equal to the thickness of the shell. Surface marked by slender angular bifurcating striae, of which there are from twenty to thirty near the margin, and half as many near the umbo. One of the striae on each side of the sinus in the ventral valve is stronger and more prominent than the others near the beak. Two or three spines may usually be seen on the hinge line on each side of the beak. The interior of the dorsal valve shows a longitudinal depression and the course of the striae is well defined and strongly papillose.

This species is quite abundant in some localities occurring with *Styliola fissurella.*

Formation and locality.

New Albany shale; Helt's Mill and Scipio, Jennings County, New Albany, Lexington and Bartholomew County.

Lingula spatulata Vanuxem.

Pl. I, fig. 1.

L. spatulata Hall, Pal. N. Y., 1867, Vol. IV, p. 13, Pl. 1, fig. 1.

Hall's description.—"Shell small, subspatulate or subelliptical, moderately convex, attenuate toward the beak, the ventral valve being more acute; greatest width across the middle of the shell; length (which is scarcely three-tenths of an inch) about twice as great as the width. Surface marked by fine concentric striae, and in the exfoliated shells, by faint radiating striae."

I have found this a common species at two localities.

Formation and locality.

New Albany shale; Crothersville, Lexington and Falls of the Ohio.

* Geol. Surv. of Ind., 1874, p. 180.

Barriosella subspatulata Meek & Worthen.

B. subspatulata Hall & C., Pal. N. Y., VIII, Pt. I, 1892, p. 63, Pl. 2, figs. 14-16.

Shell narrow, elliptical, sides regularly curving or sometimes nearly straight; length a little less than twice the width. Anterior end broadly rounded, posterior extremity more or less acute. The surface is marked by fine concentric striae. Near the front and sides in perfectly preserved shells, the surface shows under a good lens a delicately corrugated surface ornamentation. No radiating striae have been observed.

This species is abundant in many localities.

Formation and locality.

New Albany shale; Helt's Mill, Jennings County, Crothersville, Delphi and Rockford.

Schizobolus concentricus (Vanuxem).

Pl. I, figs. 2, 3.

Discina truncata Hall, Pal. N. Y., 1867, p. 23, Pl. 1, fig. 15; Pl. 2, figs. 36, 37.

Hall's description.—"Shell ovate, the anterior end broader; valves depressed-convex. Dorsal valve with the apex near the posterior margin, and directed backwards; posterior margin very abruptly rounded or truncate.

"Ventral valve with the apex submarginal; foramen extending nearly or quite to the posterior margin, which is indented. Surface marked by fine concentric striae and faint radiating undefined lines."

This is an abundant species in the black shale at the Falls of the Ohio. The posterior margin is often rounded and the shell nearly circular.

Formation and locality.

New Albany shale; Falls of the Ohio.

Orbiculoidea lodiensis (Vanuxem)?

Pl. I, fig. 4.

Discina lodiensis Hall, Pal. N. Y., 1867, Vol. IV, p. 22, Pl. 1, fig. 14; Pl. 2, fig. 35.

The specimen, which is referred with some doubt to this species, is the impression of a rather poorly preserved pedicle valve. The outline of the impression is very indistinct and it is not entirely

certain that the pedicle slit extends to the margin of the valve as indicated by the figure. The specimen measures three-twentieths of an inch in length.

Formation and locality.
New Albany shale; Falls of the Ohio.

Stropheodonta sp.

Pl. I, fig. 6.

Associated with *Spathiocaris emersoni* several specimens of a small species of *Stropheodonta* have been found in a drab colored band of shale in the Black shale. All of the specimens are exfoliated and too poorly preserved to permit of detailed description.

Formation and locality.
New Albany shale; Delphi.

PELECYPODA.

Paleoneilo sp.

Pl. I, figs. 8, 8a.

Shell small subovate, length nearly one-third greater than the height. Anterior end short and regularly rounded. Basal margin regularly rounded, hinge line straight posterior to the beaks; anterior to the beaks it descends to the anterior margin. Valves gibbous in the umbonal region; nearly uniformly convex, no umbonal slope. Beaks at about the anterior third, slightly elevated above the hinge line. Anterior and posterior muscular scars strongly marked. Six or seven small impressions near each of the beaks marks the position of the points of attachment of umbonal muscles. A distinct sharp ridge extends from the upper angle of the anterior and posterior muscular scars along the cardinal line almost to the beaks, indicating the position of corresponding grooves in the valves.

The specimen described is a cast and preserves no surface markings.

Formation and locality.
New Albany shale; Delphi.

Panenka radians (Hall).

Cardiola radians Whitfield, 6th Ann. Rep. Ind. Geol. Surv. 1875, p. 126.

Whitfield recognized this species or a species allied to it in a collection sent him from the New Albany shale of Scott County. The

poor state of preservation of specimens referred to this species and to *Panenka robusta* makes this specific determination doubtful.

Panenka sp.

Badly crushed shells which resemble *Panenka robusta* have been found in the Black shale. They are comparatively rare.

Horizon and locality.

New Albany shale; Lexington and Helt's Mill, Jennings County.

Lunulicardium fragile Hall.

L. Fragile Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 434, Pl. 71, figs. 1-14.

This species is included here on the authority of Hall, who states that "It has likewise been noticed in the Genesee shale of Ohio, and Indiana." If Hall's statement is correct, *L. fragile* is certainly a very rare species in Indiana.

Horizon and locality.

New Albany shale; locality?

GASTEROPODA.

Plethospira socialis Girty?

Pl. I, fig. 9.

Shell rather small with three rapidly expanding volutions. Spire depressed and small. The body whorl comprising about seven-eighths of the bulk of the shell. Volutions regularly rounded, nearly circular in transverse section. Umbilicus open. Surface markings not preserved. Specimens varying in diameter from 6/25 to ½ inch in diameter. Diameter usually somewhat greater than the height.

Nearly all of my specimens are considerably larger than the species described by Mr. Girty but they agree with it pretty closely in form and proportions. The entire absence of surface markings from the specimens here described, however, makes their identification with *P. socialis* very uncertain.

Formation and locality.

New Albany shale; Delphi.

Pleurotomaria sp.

Pl. I, fig. 11.

Shell turbinate, spire rather slender, apex minute. The spire consists of three volutions, increasing gradually to the body whorl, which expands more rapidly and is a trifle ventricose. Aperture oval.

The specimens preserve only traces of the surface markings. The body whorl shows a revolving band limited by strong revolving lines. Transverse striae mark the volutions of the spire.

Formation and locality.

New Albany black shale; Delphi.

Macrochilina? *sp.*

Pl. I, fig. 10.

Shell conical; spire gradually tapering to the apex which is minute. Volutions four and a half or five; regularly rounded and nearly circular in transverse section. Aperture undetermined.

All of the specimens observed are interior casts, preserving none of the surface markings.

Formation and locality.

New Albany shale; Delphi.

Straparollus sp.

Pl. I, fig. 12.

Shell small; spire slightly elevated above the body whorl. Volutions three or four, expanding gradually to the outer whorl, which increases more rapidly. Umbilicus equals about one-third the diameter of the shell. Transverse section of volutions subquadrangular to rounded. Some of the specimens preserve traces of transverse striae.

The ridges on the outer whorl shown in the figure have developed during the pyritization of the shell.

The collections contain a number of specimens of this shell, all in a very poor state of preservation.

Formation and locality.

New Albany shale; Delphi.

Styliola fissurella Hall.

Pl. II, fig. 9.

S. fissurella Hall, Pal. N. Y., Vol. V, Pt. II, p. 178, Pl. 31A, figs. 1-30.

Hall's description.—"Form an extremely slender, elongate cone, like the point of a small needle. Apical portion of the tube solid. Apex extremely minute, often bulbiform, and very gradually enlarging to the mouth. Surface often smooth and without any visible ornamentation, so far as can be determined; or with fine striae of

growth which are unequally developed on different parts of the shell; and also with fine longitudinal striae, which may be present with or without transverse striae. Usual length from one to two, sometimes two and a half and rarely five millimeters."

This species occurs in the New Albany shale at some localities in great abundance; several thousand individuals often cover a few square inches of shale. The shells are nearly always crushed, a depressed line marking the place of fracture along the middle of the shell. Nearly all of the specimens seem to be without surface ornamentation. A few, however, have fine longitudinal striae.

Formation and locality.

It occurs in the New Albany shale associated with *Chonetes lepida* and *Leiorhynchus mesacostalis,* and in such abundance that I have designated the faunal zone in which it occurs as the *Styliola fissurella* zone (see Bull. Am. Pal. No. 12, p. 111); Falls of the Ohio, Lexington, Helt's Mill, Jennings County, Scipio, and Newbern.

CEPHALOPODA.

Goniatites wabashensis n. sp.

Pl. II, figs. 4, 4a.

Shell small, discoid, the thickness of the disc being about one-third of the diameter. Umbilicus large, exposing all the volutions, which are five or six in number. Outer volutions embracing the inner ones very slightly or not at all. The periphery of the outer volution is flattened or very slightly compressed and the sides rounded. The sutures of the septa in passing from the inner umbilical margin of the volution describe a gentle backward curve on the side of the volution, and then swing forward to the peripheral face where they make an abrupt retral curve describing a deep sinus in the middle of the periphery. The surface is marked by fine transverse striae which arch backward on the periphery of the volution. Chamber of habitation and siphuncle unknown.

This species is so unlike the other form here described as to require no comparison with it. Only two specimens have been found.

Formation and locality.

New Albany shale; Delphi.

Goniatites delphiensis n. sp.

Pl. II, figs. 1, 1a, 2, 3.

Shell small, flattened or slightly convex, periphery rounded. Volutions about four and a half. Inner volutions embraced in the dorsal

groove of the succeeding ones to the depth of from one-half to three-fourths of their dorso-ventral diameter. The ratio of the dorso-ventral to the transverse diameter of the outer volution about as three to four. The umbilicus is large and open, exposing the inner margin of all the volutions and the minute bulbous protoconch. The sutures in passing outward from the dorsal groove make a very slight forward curve; in crossing the umbilical angle, they curve gently backward, and then make a deep forward curve to the middle of the lateral face of the volution, whence they curve abruptly backward to the margin of the periphery, the septa bend forward from the margin of the periphery, describing a shallow saddle on each side of the middle of the periphery, with a short narrow backward pointing lobe between them. The chamber of habitation has not been observed.

The surface in the earlier or nepionic and neanic stages is marked by prominent transverse ridges, which bend backward slightly in crossing the periphery. These annulations are very prominent and well developed in the earlier volutions. In the later ones they decrease in strength and finally disappear, transverse, rather crowded striae taking their place. The later representatives of the annulations do not extend entirely across the volution but are confined to the umbilical margin.

The individuals vary in size from one-eighth to one and a quarter inches in diameter.

This species rather closely resembles *Goniatites simulator* Hall in the character of the sutures, but the peripheral lobes and saddles seem to be somewhat shallower than in that species.

Formation and locality.
New Albany shale; Delphi.

Orthoceras sp.

Pl. II, fig. 8.

Shell small, straight, and regularly expanding from the apex. Transverse section circular. Initial extremity and chamber of habitation unknown. Thickness of air chambers equal to two and a half or three times the width of the shell. Siphuncle unknown.

Formation and locality.
New Albany shale; Delphi.

CRUSTACEA.

Spathocharis emersoni Clark.

Pl. II, figs. 5, 6, 7.

Carapace elliptical or subquadrate in general outline. The cephalic or rostral cleft extends about one-third the length of the shield. The sides of the cleft diverge from 20 to 45 degrees. All of the specimens are flattened and the original elevation and character of the apex is not shown. Anterior extremities of the carapace rounded; posterior extremity rounded or subtruncate. Surface marked by fine striae following the outline of the margin of the carapace. These are very indistinct in some individuals. The radiating lines on the posterior extremity mentioned in Clark's description of *S. emersoni* have not been recognized. The test consists of a very thin, black chitinous substance.

This species has been found at one locality only, where it is rather common in a bed of drab colored shale occurring in the New Albany shale. Associated with it occurs a small species of *Stropheodonta* and *Barriosella subspatulata.*

Formation and locality.

New Albany shale; Delphi.

DEVONIAN LIMESTONE FOSSILS.

BRACHIOPODA.

Orbiculoidea doria Hall.

Pl. III, fig. 7.

Discina doria Hall, Pal. N. Y., 1867, Vol. IV, p. 19, Pl. 2, figs. 19-22, 31.

Hall's description.—"Shell subcircular or oblate, the transverse diameter usually the greater. Dorsal valve convex; apex elevated subterminal. Ventral valve flat or concave, the apex excentric; foramen comparatively large, oval, with margins depressed. Shell thin. Surface marked by fine concentric striae, and the cast by folds or wrinkles in the same direction."

Seven specimens in Mr. Green's collection are referred to this species with some doubt. The dorsal valve which is partially exfoliated, shows very faint traces of concentric striae near the margin. The apex is less elevated and more terminal than in Hall's figures. The pedicle valve is marked by ten or twelve strongly impressed con-

centric lines, and the spaces between them by very fine concentric striae. Six specimens are attached to *Spirifer granulosus*.

Formation and locality.
Sellersburg beds; Clark County.

Roemerella grandis (Vanuxem).

Discina grandis Hall, Pal. N. Y., 1867, Vol. IV, p. 17, Pl. 1, fig. 18; Pl. 2, figs. 32, 33. Discina grandis Hall and Whitfield, 27th Rep. N. Y. State Cab. Nat. Hist., 1875, Pl. 9, figs. 33-35.

Hall's description.—"General form broadly and transversely elliptical, plano-convex or concavo-convex. Dorsal valve sometimes extremely elevated; apex subcentral, a little on one side of the transverse axis. Ventral valve usually moderately concave; foramen reaching from the center or near the center towards one side but varying somewhat in different individuals. Surface marked by fine concentric striae, crowded near the center, and more distant and sharply elevated towards the margin."

This species is comparatively rare. The specimens at hand, numbering six, measure from one to one and two-fifths inches in their transverse diameter. The cast of the dorsal valve figured has a depth of three-sevenths of an inch, and a transverse diameter of one and one-tenth inches.

Formation and locality.
Sellersburg beds; Charlestown.

Pholidops sp.

Pl. III, fig. 4.

A few unattached valves have been found in the *Spirifer acuminatus* zone of northern Indiana which are referred to this genus.

The specimen figured is marked by strongly lamellose lines of growth. The apex is moderately elevated and slightly nearer the posterior than the anterior margin.

Formation and locality.
Jeffersonville limestone; Bunker Hill.

CRANIA.

A.	Surface with radiating striae.		
	b. Dorsal valve depressed posterior to the beak.		*C. greenei.*
	bb. Dorsal valve not depressed posterior to the beak.		
		c. Striae very fine.	*C. sheldoni.*
		cc. Striae not very fine.	*C. crenistria.*
AA.	Surface without radiating striae.		*C. granosa.*

Crania sheldoni White.

Pl. III, fig. 2.

C. bordeni Hall, 24th Rep. N. Y. State Cab. Nat. Hist., 1872, p. 187.

Hall and *Whitfield's original description.*—"Shell depressed conical about half as high as wide; beak subcentral, slightly nearer the anterior end. Surface marked by fine radiating striae, and somewhat strong lines of growth, giving a rugose character to the surface, especially toward the margin."

The specimens at hand show from 12 to 15 striae near the margin in the space of one-tenth of an inch. The striae are sometimes irregular in character, swelling at intervals into node-like expansions.

This is a rare species.

Formation and locality.

Sellersburg beds; Charlestown.

Crania crenistria Hall.

Pl. III, fig. 1.

C. crenistria Hall, Pal. N. Y., 1867, Vol. IV, p. 28, Pl. 3, figs. 13-16.

Hall's description.—"Dorsal upper valve very depressed, conical, subcircular apex central or subcentral, a little inclined. Surface marked by sharp elevated crenulate striae reaching almost to the apex (which is quite smooth), and increasing by interstitial additions."

Mr. Green's collection contains four specimens of this species—the only specimens I have seen. Two of these are attached to Brachiopods and two of them to a *Platyceras;* one of these is attached inside the mouth of the shell.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Crania granosa Hall and Clarke.

Pl. III, fig. 3.

C. granosa Hall and Clarke, Pal. N. Y., VIII, Pt. I, 1892, p. 180, Pl. 4H, figs. 19-20.

Dorsal valve greatly depressed, shell subcircular, apex nearly central. Surface covered with fine granules and marked by a few concentric lines of growth.

I have seen but one specimen of this species which is attached to a *Stropheodonta.*

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Crania greenei Miller.

C. greenei Miller, 18th Rep. Ind. Geol. Surv., 1894, p. 310, Pl. 9, fig. 7.

Miller's original description.—"Shell large, subcircular, broadly convex, depressed posterior to the beak, height about one-third the diameter. Apex subcentral, obtuse. Surface bears a few concentric imbricating lines of growth, and is marked by irregular transverse striae, some of which are deflected on the anterior side of the shell, and also by faint radiating lines that somewhat sculpture the surface especially towards the margin. Lower valve and muscular impressions unknown."

Formation and locality.

"Upper Helderburg;" Falls of the Ohio.

Crania sp.

Pl. III, fig. 8.

The specimen figured is a ventral valve which I have not been able to identify with any described species.

Valve transversely subovate. The margin of the interior is marked by a broad thickened ridge around the front and sides, and by a distinctly developed cardinal area at the posterior side of the shell. Muscular scars deeply impressed. Vascular sinuses covering the space at the sides and in front of the anterior adductors. The exterior of the valve shows no indication of having been attached. It is marked by coarse lammelose lines of growth, giving an irregular, roughly flattened surface. The dorsal valve has not been seen. The species is based on a specimen in Mr. Green's collection.

Formation and locality.

Sellersburg beds; Charlestown.

Craniella hamiltoniae Hall.

Pl. III, fig. 5.

Chaniae hamiltoniae Hall, Pal. N. Y., 1867, Vol. IV, p. 27, Pl. 3, figs. 17-23.

Hall's description.—"Shell broadly oval or subcircular. Dorsal valve subconical; apex subcentral or excentric, pointed in well preserved specimens, often worn or decorticated. Exterior surface of dorsal valve marked by concentric lammelose striae. Ventral or lower valve marked by four strong impressions of the adductor muscles, which are variable in form; the posterior ones are distant, the anterior ones approximate, diverging above and assuming a some-

what cordiform appearance, the pit for the protractor muscles occupying the space between. Vascular impressions strongly digitate."

The upper valve from which the interior is here figured is very much depressed, having an elevation of about one-seventh of an inch. The exterior is entirely covered by a bryozoan growth. This is a rather rare species.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio, Pipe Creek Falls and Bunker Hill.

Glossina triangulata Nettleroth.

Lingulae triangulata Nett., Ky. Foss. Shells, 1889, p. 34, Pl. 26, fig. 1.

Nettleroth's description.—"Shell of medium size; subtriangular or broadly subovate. The lateral margins form at the apex an angle of about sixty degrees; the sides slope from apex to two-thirds the length of the shell in a straight line; from there they curve gently to basal margin, which is broadly rounded. Shell is moderately convex from beak down to front, but depressed almost flat at the margins. The greatest width is about one-third of length of shell from the front; width is smaller than length. The specimen before me measures twelve lines in length by ten lines in width. Shell itself is thick. The surface is marked by fine concentric lines of growth, and also by fine radiating striae, both of which are somewhat obscure on account of exfoliated condition of fossils, which are mostly internal casts. It appears to have some resemblance to *Lingula paliformis* of the Hamilton group, but differs from it by its shape and surface markings."

I have not seen this fossil.

Formation and locality.

Sellersburg beds; Falls of the Ohio, Ky.

Cyclorhina nobilis Hall.

Pl. VII, fig. 3.

C. nobilis Hall and Clarke, Pal. N. Y., VIII, Pt. II, 1893, p. 207, Pl. 61, figs. 1-12.

Shell large, subtriangular biconvex; the dorsal valve being the more convex. Beak of ventral valve large and obtuse. Surface covered by very sharply angular plications of which there are from 26 to 33 on each valve. Plications crossed by fine sharp striae which

crenulate the tops of the plications. These striae are seldom preserved, only two of the fourteen specimens at hand showing them. Fold and sinus well developed, moderately broad with from six to eleven plications on each.

The large obtuse beak of the ventral valve serves to distinguish this species from some of the Camarotoechias which it somewhat resembles as ordinarily preserved.

Formation and locality.

Jeffersonville limestone; Charlestown, Falls of the Ohio, Bunker Hill, Pipe Creek Falls and Little Rock Creek, Cass County.

CAMAROTOECHIA.

A. Shell gibbous or subglobose.
  b. Gibbous and transversely subelliptical. Plications grooved toward the front in old shells. *C. sappho.*
  bb. Rotund or subglobose in outline. Plications not grooved, but distinctly rounded. *C. congregata.*
AA. Shell not gibbous or subglobose.
  c. Plications angular, fold well developed. *C. nitida.*

Camarotoechia sappho Hall.

Pl. VII, fig. 4.

Rhynchonella (Stenocisma) sappho Hall, Pal. N. Y., 1867, p. 340, Pl. 54, figs. 33-43; Var. Pl. 55, figs. 47-52.

Shell gibbous and transversely subelliptical in mature specimens to broadly subtrigonal in young shells. Beak of ventral valve acute and moderately incurved; cardinal slopes concave. Surface covered with rounded to subangular plications which in old shells are marked in the center with a fine thread-like line toward the front of the shell.

Fine, closely arranged concentric striae cross the plications in well preserved specimens. The plications vary in number from 15 to 18 in young shells and from 20 to 28 in mature specimens; from five to eight of these occupy the fold and sinus. Those on the sides of the dorsal valve curve abruptly to the margin of the shell. The sinus begins about the middle of the ventral valve; the fold becomes conspicuous only toward the front of the shell. The specimen figured is the largest in the collection.

Formation and locality.

Jeffersonville limestone and Sellersburg beds; Charlestown and Pipe Creek Falls.

Camarotoechia carolina Hall.

Rhynchonella (Stenocisma) carolina Hall, Pal. N. Y., IV, 1867, p. 337, Pl. 54, figs. 14-19.

Hall's description.—"Shell ovate, moderately gibbous, a little produced in front and broadly sinuate; length and breadth about equal.

"Ventral valve convex on the upper part, curving gently to the margins and a little convex along the cardinal slope, sometimes nearly flat below; beak a little incurved or nearly straight; sinus beginning at about one-third the length of the shell from the apex, very gradually depressed and not abruptly incurved in front, making a broad shallow sinus with curving sides, the limits of which are strongly defined. Dorsal valve moderately gibbous and regularly arcuate from summit to base, the sides more abruptly curved; mesial fold becoming defined below the middle of the shell, its summit convex and the sides not abruptly limited.

"Surface marked by about 20 to 25 obtusely angular plications; those of the margins becoming obsolete and about four or five depressed in the sinus, with a corresponding number on the dorsal fold, which are stronger than the rest; a single one on each side of the sinus and fold, partially depressed or elevated and smaller than the others. The shell has been marked by elevated thread-like striae."

This species has been figured by Nettleroth (Ky. Foss. Shells, Pl. 13, figs. 1-3, 34, 35). Three of his figures, however, 1-3, appear to belong to *Cychlorhina nobilis* instead of *C. carolina.*

Formation and locality.

"Corniferous" (Jeffersonville limestone); Falls of the Ohio (Nett.).

Camarotoechia congregata (Conrad).

Rhynchonella contracta Hall, Pal. N. Y., IV, 1867, p. 351, Pl. 55, figs. 26-39.

Shell subglobose, length and width nearly equal, thickness to length as five to six. Dorsal and ventral valves slightly convex or nearly flat toward the beaks. Sides and front of shell curving abruptly to margin of valves. Surface marked by from 14 to 17 strong rounded plications of which from five to six in each valve occupy the sinus and fold. Mature specimens, according to Hall, have from 18 to 22 plications on each valve. I am able to refer but three rather small specimens in my collection to this species.

Formation and Locality.

Jeffersonville limestone; Pipe Creek Falls.

Camarotoechia nitida n. sp.

Pl. VII, figs. 8, 8a.

Shell small, subtrigonal, length and breadth nearly equal, thickness equal to two-thirds of the width; front straight, cardinal area slightly concave. Dorsal valve flat; mesial fold perceptible only at the front of the shell. Ventral valve slightly convex toward the beak; the sinus is wide and shallow, beginning between the middle and front of the shell.

Surface covered by from 15 to 17 rounded to subangular plications, of which there are from six to seven on the dorsal fold and from five to six in the sinus. The plications curve abruptly at the front and sides to the margins of the valves.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls.

Camarotoechia tethys (Billings).

Rhynchonella (Stenocisma) tethys Hall, Pal. N. Y., IV, 1867, Pl. 54, figs. 1-8.

Shell subtrigonal, usually wider than long, but length and breadth sometimes equal. Dorsal valve depressed convex in young and medium sized shells, more gibbous in larger individuals. Ventral valve slightly convex toward the beak. The fold and sinus are well developed and originate about two-thirds of the distance from the front to the beak. Surface covered by from 14 to 18 angular plications, of which from four to six occupy the fold and sinus. Fine striae which are seldom preserved cross the plications.

Some specimens show one or more strong lines of growth. A specimen in Green's collection which appears to be a variety of this species has 29 plications on each valve, five of which occupy the sinus and six the fold.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown, Bunker Hill and Pipe Creek Falls.

RHYNCHONELLA.

A. Plications few, developed only near the front and sides.
- **b. Fold and sinus prominent and well developed.** *R. gainesi.*
- **bb. Fold and sinus not well developed.** *R. gainesi* var. *cassensis.*

AA. Plications numerous and well developed.

c. Shell much flattened; fold and sinus obscure or wanting. ***R. depressa.***

cc. Shell moderately convex, fold and sinus prominent toward the front.

d. Greatest width at the middle of shell, sinus produced at the front. ***R. louisvillensis.***

dd. Greatest width near the front, sinus not produced. ***R. tenuistriata.***

Rhynchonella louisvillensis Nettleroth.

Pl. VII, fig. 6.

R. louisvillensis Nett., Ky. Foss. Shells, 1889, p. 77, Pl. 31, figs. 1-4.

Nettleroth's original description.—"Shell of less than medium size among the Rhynchonellidae; longitudinally suboval or subtrigonal; length and width about equal, the latter rarely exceeding the former slightly; both valves about equally convex. Ventral valve moderately convex; mesial sinus beginning in front of the umbo, is broad and flat, deepens at the base and has a considerable quadrilateral extension fitting a corresponding indentation of the other valve; it contains five plications; beak small and pointed and only slightly arched. Dorsal valve somewhat more convex than the other; mesial fold starting below the umbo, becomes prominent at the front, and contains, like the sinus, five plications; beak small, narrow and incurving into the other valve beneath the ventral beak.

"Surface ornamented by four or five rounded ribs on each side of the mesial depression or elevation; those on the lateral slopes of the dorsal valve are abruptly curving outwards and downwards."

Mr. Green's collection contains two specimens which appear to belong to this species, although they differ somewhat from Nettleroth's description. They have two and three plications respectively in the sinus, four on the sinus and three or four on each side of the fold and sinus. All of the plications become obsolete in the umbonal region.

Nettleroth reports having seen but three specimens of this shell.

Formation and locality.

Sellersburg beds; Charlestown and Falls of the Ohio.

Rhynchonella gainesi Nettleroth.

Pl. VII, figs. 9, 9a, 9b.

R. gainesi Nett., Ky. Foss. Shells, Mem. Ky. Geol. Surv., 1889, p. 76, Pl. 31, figs. 6-9.

Shell small; the species shows great variation in its characters; subtrigonal in its outline, front nearly straight to broadly rounded.

Dorsal valve moderately convex marked by a variable number of rounded indistinct plications, seldom exceeding eight, which are usually developed only near the margin of the valves, but sometimes extending half way to the beaks. The fold is usually well marked, extending about half way to the beak and bearing from two to four plications. Ventral valve convex toward the beak with a deep flat sinus toward the front; the surface is flat or slightly concave on either side of the sinus toward the front; sinus with from one to three faint plications toward the front; two or three plications are usually developed on either side the sinus but these are sometimes wanting. The beak is sharp and slightly incurved. Surface marked by numerous fine lines of growth.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown, Bunker Hill and Pipe Creek Falls. This shell is more common in northern than in southern Indiana.

Rhynchonella gainesi var. *cassensis*, nov. var.

Pl. VII, figs. 10, 10a.

The specimens included under the name of this variety differ from typical specimens of *R. gainesi* in being much depressed and in having a poorly developed fold and shallow sinus, which are often entirely free from plications. Some specimens, however, possess from three to five faintly developed plications near the front of the fold and sinus, and are intermediate in appearance between this variety and *R. gainesi*.

Formation and locality.

Jeffersonville limestone; Bunker Hill.

Rhynchonella tenuistriata Nettleroth.

Pl. VII, fig. 7.

R. tenuistriata Nett., Ky. Foss. Shells, 1888, p. 82, Pl. 17, figs. 27-29.

Nettleroth's original description.—"Shell rather small, subtriangular or subpentagonal; cardinal line forms a right angle at the beak; its two sides, which are somewhat concave or incurved, slope down below the middle of the shell; here they meet the lateral margins with which they form again an almost right angle; lateral margins short, about one-third the length of the shell, almost straight or very slightly convex; basal margin straight with a slight concavity.

Ventral valve less convex than the dorsal, with its greatest convexity at the umbo, from which it slopes in almost straight lines to the lateral margins; the cardinal margins deflect abruptly to meet the margin of the dorsal valve in one and the same plane; below the umbo the central portion becomes depressed, which depression increases in depth and width towards the front, where it occupies the valve to the full extent of the basal margin. This mesial sinus is rounded, its margins are not well defined, and its depth becomes only somewhat prominent at or near the front; the umbo is small, the beak elevated above that of the other valve, and very little arched. The dorsal valve is very little convex, almost flat in the umbonal region and below it to the basal margin, where a part of the front is elevated into a mesial fold. On each side of this mesial fold the valve slopes down very abruptly to the baso-lateral margins. The mesial fold is only observable at or near the front; the umbo is inflated, and the beak small and incurved into the opposite valve. The surface of both valves is covered by slender, subangular or rounded radii, of which there are five or six on each side of the mesial fold and sinus; the fold is occupied by about seven while the sinus only contains about six. These striae increase by intercallation, but not by bifurcation. Other markings of the surface are not observed."

This species is rare. I have with some doubt identified one specimen in Mr. Green's collection with it, which is here figured. This specimen has fewer striae than those described by Nettleroth, there being five in both the fold and sinus, and about the same number on each side of fold and sinus.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown and Falls of the Ohio.

Rhynchonella depressa nov. sp.

Pl. VII, figs. 5, 5a, 5b.

Shell small, flattened, trigonoid-subovate in outline; cardinal lines forming nearly a right angle at the beak, the front uniformly rounded; length and breadth about equal. Ventral valve most convex at the umbo from which it slopes regularly to the front and sides; sinus wide and very shallow or entirely obsolete, marked by five or six plications; beak acute extended and slightly incurved. Dorsal valve very slightly convex, beak incurved beneath the umbo of the opposite valve. Mesial fold obsolete or represented by a very low

broad elevation near the front, marked by five or six plications. Surface covered by from 16 to 25 plications on each valve. These are crossed by numerous fine concentric striae.

This species is rather common in northern Indiana.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls, Bunker Hill and Charlestown.

Pholidostrophia iowaensis (Owen).

Pl. VI, figs. 7, 8.

Stropheodonta (Pholidostrophia) nacrea H. & C., Pal. N. Y., VIII, Pt. I, 1892, p. 287, Pl. 15, figs. 20-24.

Shell small, semielliptical or subquadrate, broader than long; ventral valve moderately convex, the convexity approaching rather closely the inner contour of the dorsal valve; dorsal valve concave, sometimes curving abruptly toward the ventral valve near the front. Interior of dorsal valve marked by large flabelliform muscular impressions; outside the muscular impressions the interior of the valves is strongly papillose; hinge line crenulated. Surface smooth except for occasional lines of growth. The radiating lines and nacreous lustre mentioned by Hall have not been noticed on the specimens at hand.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Little Rock Creek, Cass County, Charlestown and Falls of the Ohio.

Ambocoelia umbonata (Conrad).

Pl. X, figs. 7, 7a.

A. umbonata Hall, Pal. N. Y., IV, 1867, p. 259, Pl. 44, figs. 7-18.

Shell small, plano-convex, semiorbicular in outline; width of shell slightly greater than length of dorsal valve; hinge line equal to or a little less than the greatest width of shell; cardinal extremities rounded, subangular. Ventral valve gibbous with the umbo extremely elevated and a large incurved beak; mesial sinus with a shallow but distinct linear depression, extending from the beak to the front of the shell. Area large, arched, having about one-third the height of the ventral valve and extending to the cardinal extremities. Dorsal valve slightly convex in the upper central portion, flat or convex near the sides and front. Apex inconspicuous, barely elevated above the hinge line; area equaling the thickness of the shell.

The radiating and concentric striae occurring in the New York specimens of this species are not noticeable on the Indiana shells. Average specimens of the Indiana shells measure about one-fourth of an inch in width. This is a rare shell in Indiana.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Bunker Hill, Charlestown and Louisville.

CYRTINA.

A. Plications coarse, about four on each side of the fold and sinus. *C. crassa.*
AA. Plications fine, six or eight each side of the fold and sinus.
b. Beak more or less curved or twisted, plications rounded. *C. hamiltonensis.*
bb. Beak straight, plications angular. *C. hamiltonensis* **var.** *recta.*

Cyrtina crassa Hall.

C. crassa Hall, Pal. N. Y., IV, 1867, Pl. 27, figs. 11, 12.

Hall's original description.—"Shell depressed, pyramidal (semielliptical in a dorsal view); length and breadth about at three to four; hinge line equal to the greatest width of the shell, with the extremities slightly rounded.

"Ventral valve depressed, semi-semipyramidal, convex, regularly arching from the beak and cardinal area to the front; sinus broad and rounded in the bottom; beak extended and slightly incurved over the area which has a height equal to half the length of the valve.

"Dorsal valve moderately convex, a little inflected or concave toward the extremities; mesial fold broad, moderately elevated, rounded above and strongly defined; area linear. Surface marked on each side the mesial fold and sinus by about four strong, low rounded plications, which are crossed by fine thread-like concentric striae and a few imbricating folds. Shell structure punctate."

This species has not been seen by the writer. Nettleroth reports having seen but three specimens. Hall figures a specimen from the Falls of the Ohio.

Formation and locality.

"Corniferous limestone" (Jeffersonville limestone); Falls of the Ohio and Utica.

Cyrtina hamiltonensis Hall.

C. hamiltonensis Hall, Pal. N. Y., IV, p. 268, Pl. 27, figs. 1-4; Pl. 44, figs. 26-33, 38-52.

Hall's description.—"Shell more or less triangular-subpyramidal; hinge line equal to the greatest width of the shell; proportions of

length, breadth and height variable, but frequently the width is equal to the length of the ventral valve, and the height of area is equal to the length of the dorsal valve. Surface plicate. Ventral valve quadrilateral in outline, obliquely subpyramidal, most prominent at the beak, which is very variable in elevation and straight or a little arched over the area, and not unfrequently attenuate and distorted or turned to one side; mesial sinus wide and strongly defined, rounded or subangular in the bottom; area variable, large and elevated, plane or arcuate in different degrees with the lateral margins angular, distinctly striate in both directions; fissure narrow, closed by a convex pseudo-deltidium, which is perforated above by an oval or narrowly ovate foramen. Dorsal valve depressed-convex, with a broad, more or less prominent mesial fold, which is bounded by broader furrows than those between the plications, and is sometimes extremely elevated in front; beak scarcely rising above the hinge line; area narrow linear, but quite distinct. Surface marked by about six to eight (rarely one or two more) simple rounded plications on either side of the mesial fold and sinus, and these are crossed by very fine concentric lines of growth, which at intervals become crowded and subimbricate, especially toward the margins of older shells. The finer surface marking is minutely granulose or papillose and the shell structure distinctly punctate. In some of the larger individuals there is an obscure elevation on each slope of the sinus resembling an obsolete plication. The longitudinal median septum extends for more than half the length of the ventral valve, and is continued into the cavity beneath the pseudo-deltidium. These features are shown in the casts and in transverse sections of the valve. The dorsal valve shows a double or bilobed cardinal process with the strong crural bases supporting spiral arms which are directed into the two compartments of the ventral valve, and, making numerous turns, terminate in the rostral part of the shell."

This species is not abundant but occurs at many localities in both the northern and southern Indiana Devonian.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Little Rock Creek, Cass County; Pipe Creek Falls, Newbern, Charlestown, Scipio, Paris Crossing, Kent, Clark County, and Falls of the Ohio.

Cyrtina hamiltonensis var. *recta* Hall.

Cyrtina hamiltonensis var. recta Hall, Pal. N. Y., Vol. IV, p. 270, Pl. 44, figs. 34-37.

The only specimen in the collection has a very high perfectly flat

area, dorsal valve short and rather narrow; ventral valve very steeply pyramidal, and subangular plications.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Little Rock Creek, Cass County and Falls of the Ohio.

Leptaena rhomboidalis (Wilckens).

Pl. IV, fig. 5.

Strophomena rhomboidalis Hall, Pal. N. Y., Vol. IV, p. 76, Pl. 12, figs. 16-18.

Hall's description.—"The shell is more or less semielliptical or subquadrate, varying greatly in its proportions of length and breadth; hinge line straight; cardinal extremities sometimes rounded, sometimes acute and slightly produced. The valves are geniculated and the proportions of the flattened part or disc and the recurved part of the shell are very variable, insomuch that the geniculation is sometimes little more than one of the strong concentric wrinkles. The surface of the flattened portion is marked by concentric (and sometimes interrupted) wrinkles, which, following the curve of the outline, are bent outwards, and often become obsolete on the cardinal angles. These concentric wrinkles are very variable in number, being from six to 15 or 16 upon the specimens from the same rock. The entire surface is covered by radiating, thread-like striae. In young specimens there is usually a round foramen in the apex of the dorsal valve, which becomes closed at a later period. The triangular foramen of the ventral area is partially closed by a deltidium and the apex of the ventral valve."

This specimen is abundant in some localities.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Deputy, Sellersburg and Charlestown.

Orthothetes chemungensis arctistriatus Hall.

Pl. VI, fig. 3.

Streptorhynchus chemungensis var. arctostriata Hall, Pal. N. Y., Vol. IV, 1867, p. 71, Pl. 9, figs. 1-12.

Hall's description.—"Shell semicircular or semielliptical, frequently unsymmetrical, the proportions of length and breadth varying in different individuals; hinge line straight, nearly or quite equal to or greater than the greatest width of the shell; sides nearly rectan-

gular to the hinge line or curving inwards. Ventral valve more or less convex toward the umbo and sometimes in the middle, curving downwards or flattened toward the front and sides of the shell; beak often distorted; area vertical or inclined forwards or backwards, usually unequal on the two sides of the foramen, which is closed by a strong convex deltidial plate. Dorsal valve depressed convex, sometimes nearly flat and sometimes very convex, with a narrow linear area; socket plates strong and supporting the cardinal process, which is double and has sometimes a faint ridge between the two divisions, which are themselves very short. Surface marked by sharp close radiating crenulated striae, which increase mainly by interstitial additions."

This extremely variable species is rather rare. In the specimens studied the radiating striae increase by bifurcation instead of by interstitial addition as described by Hall.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio, Lancaster, Scipio, Kent and Newbern.

Parazyga hirsuta Hall.

Pl. XI, figs. 4, 4a.

Trematospira hirsuta Hall, Pal. N. Y., Vol. IV, 1867, p. 274, Pl. 45, figs. 16-32.

Hall's description.—"Shell depressed orbicular in the young state; becoming subtrilobate by the gradual development of the mesial fold and sinus and often gibbous in the older specimens; valves subequally convex; hinge line extending about two-thirds the width of the snell. Ventral valve usually a little more gibbous than the opposite; greatest convexity above the middle of the shell, whence it curves regularly to the apex which is terminated by a circular foramen or more often truncated below by the summit of the opposite valve; contour regularly curving to the cardinal and lateral margins. The mesial sinus becomes gradually developed above the middle in full grown shells, and is very conspicuous toward the front, having the sides curving and rarely strongly defined. The false area is not visible beneath the beak. Dorsal valve regularly convex in young shells; becoming elevated in the center, and a mesial fold gradually developing itself, till in older shells it becomes very conspicuous toward the front, having the sides curving and rarely strongly defined. The false area is not visible beneath the beak. Dorsal valve regularly convex in young shells; becoming elevated in the center and a mesial fold gradually developing itself, till in old shells it becomes very conspicuous towards

the front. The sides are pretty regularly convex, and curving towards the margins. Surface marked by from 30 to 40 low rounded striae which are obscure toward the beaks, but become larger and more conspicuous towards the margin; these are crossed by fine close concentric lines of growth, and more distant imbricating lamellae. The surface ordinarily preserved is granulose, but when perfect it is covered by minute seta or spinules, the bases of which remaining give the papillose character. Entire shell structure punctate. The interior of the ventral valve shows two strong teeth, which are extended in low plates along the sides of the rostral cavity to the margins of the muscular area, which is broad, flabelliform, and scarcely defined on the front and lower lateral margins. The interior of the dorsal valve shows a strong deeply bilobed cardinal process, with the bases of slender crura; the teeth sockets are large and deep; there is a low median crest or septum, which is somewhat strong above, but dies out towards the middle of the shell. In specimens which have been cut to show the spires, these appendages are slender with about 10 or 11 turns on each side. The proportions of length and breadth are about as three to four. The largest specimen observed is a little more than three-fourths of an inch in length, by an inch and one-sixteenth in width; while many of the specimens are less than half these dimensions. A well formed specimen of about three-fourths of an inch in length by one inch, has a depth of nine-sixteenths of an inch. A very gibbous specimen measures three-eighths of an inch in length, nine-sixteenths in width and half an inch in depth."

A specimen from Charlestown slightly above the average size measures five-eighths of an inch in length, nine-sixteenths of an inch in width and three-eighths in thickness. The Indiana specimens do not preserve the fine concentric lines and minute striae described on the New York specimens. This is a rather rare fossil.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown, Falls of the Ohio and Bunker Hill.

Tropidoleptus carinatus (Conrad).

Pl. VI, figs. 4, 5.

T. carinatus Hall, Pal. N. Y., Vol. IV, 1867, p. 407, Pl. 62, figs. 2, 3.

Hall's description.—"Shell concavo-convex, semielliptical, the length sometimes equaling the width; hinge line equaling, greater or

less than the width of the shell, and the cardinal extremities sometimes rounded so as to give the shell a broadly oval form; the sides are sometimes nearly straight and the front broadly rounded. Ventral valve convex, broadly subcarinate along the middle, and sloping in a flattened curve to the lateral margins and front, which is sometimes slightly truncate or emarginate; cardinal extremities deflected, abruptly incurved at the umbo, and the apex often imperfect from the encroachment of the foramen. Area about half a line to about one line in width; its margins parallel to near the extremities, where it slopes suddenly down from the outer margin. The area is longitudinally striate, and indented by a very wide foramen. Dorsal valve moderately concave, sometimes nearly flat, often with a median depression or sinus which becomes conspicuous below the middle of the valve; apex small, projecting a little beyond the hinge line. There is a narrow area interrupted in the middle by a wide pseudo-deltidium which covers the extremity of the cardinal process. Surface marked by about 18 to 20 broad simple rounded plications which are wider than the spaces between them; the central one on the ventral valve is broader and more elevated than the others, while there is a corresponding wider and deeper depression in the middle of the dorsal valve. In rare instances the plications are bifurcated. Fine undulating concentric striae cover the surface and five stronger imbricating lamellae mark the form of the shell in its stages of growth."

This is a common fossil in the Upper Devonian of northern and southern Indiana.

Formation and locality.

Sellersburg beds; Norway, Scott County, North Vernôn, Deputy, Charlestown and Lexington.

ATHYRIS.*

A.	Shell usually more than an inch in width.	*A. spiriferoides.*
AA.	Shell usually less than one inch in width.	*A. fultonensis.*

Athyris spiriferoides (Eaton).

Pl. XI, fig. 6.

A. spiriferoides Hall, Pal. N. Y., Vol. IV, 1867, p. 285, Pl. 46, figs. 5-31.

Hall's description.—"Shell varying from transversely oval to suborbicular and sometimes subquadrate, depressed or subglobose, more or less deeply sinuate on the ventral side, with a corresponding

*The separation of *A. spiriferoides* and *A. vitata* as distinct species is based chiefly on the difference in the structure of the spires of the two forms.

elevation on the dorsal side; hinge line short, the cardinal extremities rounded. Ventral valve moderately gibbous, often regularly convex above the middle, and becoming deeply sinuate toward the front, which is frequently abruptly elevated, flattened or a little concave toward the cardinal extremities in the wider specimens; umbo gibbous, the beak incurved, and often directed in a line nearly rectangular to the plane of the longitudinal axis and covering the umbo of the opposite valve; apex perforate. Dorsal valve gibbous, much more convex than the opposite valve; umbo prominent, outline regularly convex above the middle and curving abruptly to the sides; the usually defined mesial fold becomes visible below the middle of the valve and usually very conspicuous toward the front, which is abruptly elevated. Surface marked by concentric lines of growth, and the lamellae often extended and closely imbricated; fine interrupted and scarcely distinct radiating striae, which appear like ducts within the substance of the shell, marking the surface in many specimens. The upper part of the shell is sometimes nearly free from imbricating lamellae, but they become crowded toward the front."

Athyris spiriferoides is much rarer than *A. fultonensis,* which differs from it externally only in its smaller and more gibbous form.

Formation and locality.

Sellersburg beds; Charlestown.

Athyris fultonensis (Swallow).

A. vitata Hall, Pal. N. Y., Vol. IV, 1867, p. 289, Pl. 46, figs. 1-4.

Hall's description.—"Shell ovate, subquadrate, gibbous with the mesial fold and sinus distinct; front conspicuously sinuate; hinge line short; cardinal extremities rounded. Ventral valve gibbous above, more convex than the dorsal; umbo prominent; the beak incurved and truncated in the plane of the longitudinal axis by a rounded foramen, curving very abruptly to the cardinal and cardino-lateral margins; the center marked by a well defined mesial sinus, which is continued nearly or quite to the beak and becoming much deeper and subangularly margined towards the front. Dorsal valve a little less gibbous than the ventral, sides regularly curving; the middle of the upper part distinctly prominent, and developed below in a strong mesial fold which is abruptly elevated in front. Surface marked by regularly imbricating lamellose lines of growth, which, on the better preserved surfaces are finely crenulated on their edges and the intermediate spaces striate. Interiorly the spires of this form, in their first volution and in the accessory lamellae are quite distinct from those of *A. spiriferoides.*"

This species is abundant at many localities.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Little Rock Creek, Cass County, Bunker Hill, Falls of the Ohio, Charlestown, Watson, Kent, Sellersburg and Lexington.

ATRYPA.

A. Plications very coarse, about seven or eight in a half inch, cancellated by strong concentric lamellae. *A. spinosa.*

AA. Plications not very coarse, about 12 or 16 in a half inch, usually without concentric lamellae.

b. Shell longitudinally subelliptical in outline. *A. reticularis* var. *ellipsoida.*

bb. Shell not longitudinally subelliptical in outline. *A. reticularis.*

Atrypa reticularis (Linnaeus).

Pl. VI, fig. 10.

A. reticularis Hall, Pal. Iowa, Vol. I, Pt. 2, 1858, p. 515, Pl. 6, figs. 4, 5.

Hall's description.—"Shell depressed, suborbicular in its young state, becoming gibbous and sinuate in its mature condition; hinge line often nearly straight and almost equaling the width of the shell; valves nearly equally convex in the young state, the dorsal valve becoming more gibbous as the shell advances in age, and sometimes acquiring an undefined mesial lobe down the center. The ventral valve in the young state has the beak nearly straight and perforate at the apex, becoming incurved and finally closely bent over the beak of the opposite valve; a narrow false area is sometimes observable. Shell broadly and deeply sinuate in front."

This is one of the most abundant species of the Devonian limestones. It is subject to great variation in shape, size and surface markings. The specimens found in the arenaceous "cement rock" of the Sellersburg beds reach a considerably larger average size than those in the more pure limestones.

A specimen in Mr. G. K. Green's collection is almost entirely covered by a series of closely arranged imbricating lamellae or lines of growth, giving the shell a very roughly imbricated surface.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; throughout the Devonian.

Atrypa spinosa Hall.

Pl. VI, fig. 11.

A. spinosa; vel aspera Hall, Pal. N. Y., 1867, Vol. IV, p. 322, Pl. 53A, figs. 1-14.

Hall's description.—"Shell robust suborbicular or ovoid; width greater or less than the length; radiatingly costate and concentrically lamellose or spinose; hinge line often nearly straight, a little less than the width of the shell. Ventral valve depressed convex, becoming more convex in the upper part; nearly flat and often a little concave toward the lateral margins, and cardinal extremities depressed or broadly sinuate in part; beak abruptly rounded; apex truncate and perforate, closely appressed and overlapping the umbo of the opposite valve. Dorsal valve convex, becoming gibbous in old shells, flattened or slightly concave toward the cardinal angles, regularly curving to the sides and baso-lateral margins, and a little elevated in front but without any distinct mesial fold. Surface marked by strong rounded radiating costae bifurcating at unequal intervals, which are much stronger in the middle of the valve and become obsolete or appear as gentle undulations towards the cardinal angles. In the middle of the valves there are about seven or eight of these costae in the space of half an inch. The shell is also marked by strong concentric lamellae which are often about a line apart. In perfect shells these lamellae at the crossings of the costae are often produced into tubular spines, which, when worn off, leave the ordinary lamellose surface. The spaces between these projecting lamellae are marked by fine thread-like striae. In the separated valves the hinge line is often nearly straight, the muscular area of the ventral valve is short and broad, the length from the apex being about equal to the width. There is a slight thickening of the shell at the base of the rostral cavity. The surface around the muscular area is papillose, and limited by a thickened border except in part, where it is discontinued. Fine vascular markings are sometimes visible near the margin. In the dorsal valve there is a thickened septum in the upper part of the muscular area. The spires of full grown individuals have about fifteen turns in each."

This is a rare species as compared with *A. reticularis.*

Formation and locality.

Sellersburg beds; Falls of the Ohio and Charlestown.

Atrypa reticularis var. *ellipsoida* (Nettleroth).

A. ellipsoida Nett., Ky. Foss. Shells, 1889, p. 90.

Nettleroth says of this shell that "it resembles in every feature except the form" *Atrypa reticularis.* But Nettleroth considered the elliptical form a specific character and based the species *A. ellipsoidea* upon it.

Specimens of *Atrypa reticularis* which are longer than wide and approach somewhat the elliptical form, are not uncommon. The variation in shape is so great in *Atrypa reticularis* that it seems preferable to regard *A. ellipsoidea* as a variety of *A. reticularis.*

Formation and locality.

Jeffersonville limestone; Falls of the Ohio (Nettleroth).

CHONETES.

- A. Cardinal extremities produced. *C. acutiradiata.*
- AA. Cardinal extremities not produced.
  - b. Shell large.
    - c. Nine to fifteen radiating striae in the space of two-tenths of an inch.
      - d. Ventral valve extremely gibbous, striae rounded, dorsal valve profoundly concave, striae rounded. *C. arcuatus.*
      - dd. Ventral valve usually moderately convex, striae slender and rather sharply angular, dorsal valve not profoundly concave.
        - e. Five to seven spines on each side the beak (frequently not visible). *C. coronatus.*
        - ee. Two spines on each side the beak? **C. subquadrata.*
    - cc. Twenty to twenty-four radiating striae in the space of two-tenths of an inch. *C. manitobiensis.*
      - f. Radiating striae about sixty. *C. yandellanus.*
      - ff. Radiating striae twenty-six to thirty-four. *C. vicinus.*
      - fff. Radiating striae eight to twenty-six. *C. mucronatus.*

Chonetes manitobiensis Whiteaves.

Pl. IV, fig. 10.

C. manitobiensis Whiteaves, Contr. to Can. Pal., 1892, Vol. I, p. 281, Pl. 37, figs. 1, 2.

* The synopsis may be inaccurate with reference to the number of striae in this species. It was described without figures and the description is not very full.

Whiteaves's original description.—"Shell small, concavo-convex, strongly compressed, transversely semielliptical, about twice as broad as long and broadest at the hinge line; cardinal extremities angular and very slightly produced; sides rounded in front; anterior margin nearly straight or but faintly convex in the center. Ventral valve compressed convex, its cardinal border armed on each side of the beak with three or four slender and widely divaricating spines, which increase in length outward; its beak inconspicuous, minute and not projecting, its hinge area narrow with a small triangular fissure. Dorsal valve shallowly convex, its beak minute and its hinge area narrower than that of the ventral. Surface marked with very minute radiating raised lines, which increase in number at variable distances from the beaks by bifurcation or intercalation, so that around the outer margin as many as from seventy to a hundred can be counted under a lens. In addition to these, the exterior of well preserved specimens is marked with exceedingly fine and close-set concentric raised lines. Interior of the valve minutely papillose. Muscular impressions unknown. The dimensions of two average specimens are as follows: Of one, maximum length nearly ten millimeters, greatest breadth nineteen; of another, length ten millimeters and a quarter, breadth twenty."

The shells referred to this species do not differ from the above description except in the number of radiating striae. Specimens on which the striae were counted have from 120 to 150 near the margin and 23 to 25 were counted on the space of two-tenths of an inch. Well preserved shells show from two to three slender spines pointing outward on each side the beak. Many specimens show a wide but indistinct mesial depression on the ventral valve. A rather large specimen measures nine-tenths of an inch in width, five-tenths of an inch in length and one-tenth of an inch in thickness in the thickest part of the shell.

This species is extremely abundant at a single locality in northern Indiana, where it is associated with *Sp. mucronatus.*

Formation and locality.

Sellersburg beds; Little Rock Creek, Cass County.

Chonetes arcuatus Hall.

Pl. IV, figs. 6, 6a.

C. arcuatus Hall, Pal. N. Y., Vol. IV, 1867, p. 119, Pl. 25, fig. 7.

Hall's description.—"Shell semielliptical or approaching to semicircular; the cardinal extremities often extended and auriculate.

Ventral valve arcuate, extremely gibbous or ventricose, with usually a shallow undefined longitudinal sinus extending from the umbo to below the middle or near the front of the shell, often constricted near the cardinal extremities; umbo more or less gibbous or raised in a gentle elevation above the hinge line with the beak incurved. Hinge line in casts apparently crenulate; and on the exterior margin are ten or twelve tubular spines directed obliquely outward. Dorsal valve profoundly concave, following nearly the convexity of the opposite valve, and having the center a little elevated corresponding to the mesial depression. Surface marked by fine even rounded striae, which increase both by bifurcation and intercallation, crossed by extremely fine concentric striae with sometimes stronger subimbricating lines of growth. The surface of the cast in the ventral valve is marked by closely disposed oblong pits or pores, from the papillose inner surface of the shell. There is a concentric line extending from the apex gently receding from the hinge margin and curving inwards at the same distance from the cardinal extremities, and thence to the front of the shell, leaving the portion outside of this a little more elevated. The muscular impressions consist of a narrow central scar just below the apex of the beak, for the occlusor muscles; while there are two elongate ovate or pyriform scars, one on each side of the apex and spreading laterally just within the limits of the constricted line."

Prof. J. M. Clarke says of specimens submitted to him "that there is no important difference in specific characters, although there is a notable difference in size, our corniferous limestone species generally being larger than those from Indiana, and the type specimens quite notably so." The surface is marked by from sixty to seventy rounded striae.

This species has been found at but one locality where it is abundant.

Formation and locality.

Jeffersonville limestone; Paris Crossing.

Chonetes coronatus (Conrad).

Pl. IV, fig. 7.

C. coronatus Hall, Pal. N. Y., 1867, Vol. IV, p. 133, Pl. 21, figs. 9-12.

Hall's description in part.—"Shell transverse, somewhat broadly elliptical, the hinge line being sometimes shorter than the width of the shell and the cardinal angles rounded; in others it is often equal

to the greatest width of the shell, and its form is semioval, with the lateral margins nearly rectangular to the hinge line, the width being about once and a half as great as the length. The cardinal angles are sometimes produced in short acute ariculate extensions. Ventral valve varying from moderately convex in the younger shells to very gibbous in the older ones; often a little flattened below the umbo, and this plane space gradually widening to the front. Sometimes there is a shallow undefined depression along the middle of the valve. The outline of the valve presents a very regular convexity, while it is abruptly depressed towards the cardinal extremities, which are flattened and a little deflected to the ventral side. The dorsal valve is variably concave, sometimes following nearly the contour of the ventral valve, but often very moderately concave or nearly flat in the middle and upper part, and more suddenly deflected toward the front and lateral margins, flattened at the cardinal extremities, and a little concave just below the hinge line. The surface is marked by numerous closely arranged slender subequal striae which are bifurcated or increased by intercallation, and are continued on the cardinal extremities to within a little distance of the hinge line, beyond which the surface is marked by lamellose concentric striae. In well preserved surfaces the radiating striae are crossed by undulating concentric striae; but in the greater number of specimens these are not preserved and the radiating striae have a fibrous appearance. The cardinal margin of the ventral valve is furnished with five, six or seven oblique tubular spines on each side of the apex, though usually only three or four are visible. The ventral area is usually narrow, sublinear, though often perceptibly triangular; the foramen is of moderate size, partially closed by a convex pseudo-deltidium, and the lower part occupied by the cardinal process. The dorsal area is linear, often more than half as wide as the ventral area, with a triangular space in the middle occupied by the cardinal process. * * *"

An average specimen of this shell shows 12 striae in the space of two-tenths of an inch, and about 70 around the margin of the shell. This is a rather rare species.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Lexington, Charlestown and Deputy.

Chonetes acutiradiatus Hall.

C. acutiradiatus Hall, Pal. N. Y., 1867, Vol. IV, p. 120, Pl. 20, fig. 5.

Hall's description.—"Shell nearly semicircular, sometimes a little more than twice as wide as long; the cardinal extremities produced.

Ventral valve moderately convex, sometimes a little gibbous in the upper part and frequently flattened or depressed at or below the middle; umbo little elevated above the hinge line; greatest convexity above the middle, from whence it curves gently to the front, somewhat abruptly depressed toward the cardinal extremities, which are subauriculate and nearly flat. In two individuals there is a distinct longtitudinal sinus in the middle of the valve. Dorsal valve unknown. Surface marked by regular subequal rounded or subangular striae, which are often irregularly bifurcated toward the margin or increased by intercalations, and sometimes are nearly simple throughout their length below the umbo, those of the cardinal extremities being very irregular or nearly obsolete. Hinge line marked on each side of the center by four or five strong tubular spines, which are directed obliquely outward. The sinus in the ventral valve is not uniform, and though evidently a normal character where it occurs, it can not be relied upon as characterizing the species."

This fossil is reported to be rare by Nettleroth.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio (Nettleroth, Hall).

Chonetes subquadratus Nettleroth.

C. subquadratus Nett., Ky. Foss. Shells, 1889, p. 67.

Nettleroth's original description.—"Shell as (a?) chonetes of medium size; subquadrate, hinge line somewhat shorter than the greatest width of shell; cardinal extremities rounded; lateral margins slightly curved, almost straight except in their basal part which is regularly curved into the basal margin; central half of the front is straight or only slightly curved. Ventral valve only moderately convex in the central portion, which curves regularly from its middle to apex and base; the slope toward the lateral and cardinal margins is more abrupt, causing a flattening of the valve along the lateral borders and producing between the cardinal extremities, which are little deflected, and the umbo a shallow concavity; umbo sharply defined and moderately elevated; the beak small, pointed and incurved over the hinge area; the area is small forming a low triangle which is divided by a small triangular fissure; the foramen is partly closed by the cardinal process of the opposite valve. The margins of the cardinal area are provided with two round tubular spines on each side of the beak, which appear from their stumps to have an outward direction. The dorsal valve is concave, corresponding in its depression with the convexity of the ventral valve; its hinge line is narrow or linear. The surface of both valves is covered by fine

rounded or subangular radiating striae which increase partly by intercalation but mostly by bifurcation on the ventral valve, while it is the reverse on the dorsal valve, where very few of the striae dichotomize, but a great many short ones are implanted. The specimen before me, the only one so far known, measures seven and one-half lines in length and two lines in depth. It differs from the other shallow Chonetes by its greater size and from the larger species by its shallowness."

A rare species.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio (Nettleroth).

Chonetes yandellanus Hall.

Pl. IV, figs. 8, 8a.

C. yandellana Hall, Pal. N. Y., Vol. IV, 1867, p. 123, Pl. 20, fig. 4.

Hall's description.—"Shell semioval, more or less gibbous; hinge line equaling the greatest width of the shell. Ventral valve regularly convex, abruptly depressed toward the cardinal angles, which are nearly flat and very slightly deflected toward the ventral side. Dorsal valve with the concavity a little less than the convexity of the opposite valve. Area of the ventral valve parallel with the longitudinal axis of the shell nearly twice as wide in the middle as near the extremities; foramen comparatively large, with margins projecting and the opening filled by the cardinal process of the opposite valve. Dorsal area extremely narrow, being barely a defined line. Surface marked by fine somewhat equal striae which increase by bifurcation and intercalation till there are from sixty to seventy on the margin of the shell. The cardinal margin of the ventral valve bears three or four short oblique spines on each side of the center. The interior of the ventral valve shows strong dental lamellae and the muscular impressions are pretty well defined. The dorsal muscular impressions are well defined and between them there is a strong mesial ridge which is extended in a bidentate cardinal process. The lower half of the surface is strongly papillose."

This species is very abundant in the "cement rock" in southern Indiana.

Formation and locality.

Sellersburg beds; Charlestown, Watson, Falls of the Ohio.

Chonetes mucronatus Hall.

Pl. IV, fig. 11.

C. mucronata Hall, Pal. N. Y., 1867, Vol. IV, p. 124, Pl. 20, fig. 1; Pl. 21, fig. 1.

Hall's description.—"Shell small, semioval, moderately convex, nearly flat, (often flattened in the shale and gibbous in the limestone); cardinal line equaling or a little greater than the middle of the shell below; the extremities sometimes salient. In the original specimens of this species from the Marcellus shale, the ventral valve is slightly convex or nearly flat, one-fourth to one-third wider than long; the hinge extremities are rarely a little produced, but the spines being in the direction of the hinge line often give it the appearance of extreme extension. The dorsal valve is very moderately concave or nearly flat. The surface is marked by twenty to twenty-four or twenty-six nearly simple subangular striae, which are not so wide as the spaces between them. Sometimes one, two or three of these striae are bifurcated toward the margin. The radiating striae are crossed by extremely fine concentric elevated striae. The cardinal margin shows two and rarely three spines on each side of the center, which are abruptly bent outward so as to lie nearly parallel to the hinge line, and the outer one extending much beyond the cardinal extremity. The area is very narrow."

A well preserved specimen in Mr. Green's collection has 20 plications on the ventral valve with two strong spines on each side the beak and a third slightly developed nearer the beak. A sharp low median septum extends not quite one-third the distance from the area to the front of the shell. The dorsal valve of another specimen shows the cardinal process to be trilobed at the extremity.

Another specimen repesenting the variety originally described by Hall as *C. latticosta* is very gibbous and has only eight simple rounded plications on each valve.

This is rather a rare shell.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown, Falls of the Ohio and Sellersburg.

Chonetes vicinus (Castelnau).

C. deflecta Hall, Pal. N. Y., 1867, Vol. IV, p. 126, Pl. 21, figs. 7, 8.

Hall's description.—"Shell semielliptical; length and width as four to five or eight to nine, but rarely proportionally wider. Ventral

valve extremely gibbous regularly arched, the greatest elevation being above the middle of the length; abruptly depressed towards the cardinal angles, which are flattened with the extremities deflected toward the ventral side. The umbo is a little elevated above the cardinal margin, and the minute apex (in perfect specimens) projects a little over the area. Dorsal valve deeply concave, but not equaling the convexity of the ventral valve. Area of the ventral valve narrow, with the margin declining in a gentle curve to the extremities; the triangular foramen is partially closed by a pseudo-deltidium, and the aperture occupied by the cardinal process of the upper valve. Dorsal area more than half as wide as the ventral and marked in the middle by a wide triangular callosity. Surface of the ventral valve marked by from twenty-six to thirty or thirty-four subangular or sometimes rounded striae, which are often increased by bifurcation or intercalation toward the margin. In those with fewer striae they are sharp, more abruptly elevated, and only half as wide as the interspaces, while in those with a larger number, the striae and interspaces are equal, but sometimes the striae become fuller and more rounded, and the interspaces proportionally less in width. The striae on the dorsal valve correspond essentially with those on the ventral valve, and there is a considerable space at the cardinal angles of each valve destitute of striae. Fine, closely arranged concentric striae are visible on the surface of well preserved specimens. The interior of the dorsal valve shows a slender elongate cardinal process which is scarcely bifid at the extremity, and has on each side a little below the apex, a minute lateral process for muscular attachment. The dental sockets are limited on the upper side by a narrow ridge, and on the lower side by a stronger oblique ridge which supports the base of the cardinal process. The two pairs of occlusor muscular imprints are pretty well defined. Beyond the muscular impressions the surface is covered by elongate papillae, the marks of the striae being scarcely distinct. The interior of the ventral valve shows strong dental lamellae; a somewhat broad and angular median ridge terminates above the middle of the valve. The occlusor muscular imprints are distinctly marked; and outside of these, the muscular impressions are pretty well defined. Beyond the muscular impressions the surface is covered by elongate papillae, the marks of the striae being scarcely distinct. The interior of the ventral valve shows strong dental lamellae; a somewhat broad and angular median ridge terminates above the middle of the valve. The occlusor muscular impressions have not been observed; and those of the divaricator muscles are wide and spreading, but not distinctly defined. The

cavity of the shell is abruptly rounded below and the shell abruptly deflected at the sides, leaving the cardino-lateral margins nearly flat. The surface is finely pustulose in the middle, a little more coarsely pustulose along the deflected line, and nearly or quite smooth towards the margins."

A few specimens occurring in the Devonian chert are referred to this species.

Formation and locality.

Jeffersonville limestone; Newbern.

Conchidium knighti (Nettleroth)?.

Pentamerus knighti Nett., Ky. Foss. Shells, 1889, p. 57, Pl. 29, figs, 1, 2, 17.

Nettleroth figures two specimens of this fossil in the Fossil Shells of Kentucky, and states that they are from the Corniferous rocks near Louisville. No other specimens have been reported from the Devonian. Since this shell is known only in the Niagara elsewhere, it may be that its reported occurrence in the Corniferous is an error.

DELTHYRIS.

A. Cardinal extremities rounded, surface marked by two to four, rarely five, rounded or subangular ribs on each side the fold and sinus. *D. raricosta.*

AA. Cardinal extremities mucronate, surface marked by from three to six prominent angular plications on each side the fold and sinus. *D. sculptilis.*

Delthyris sculptilis Hall.

Pl. X, fig. 2.

D. sculptilis Hall, Pal. N. Y., 1867, Vol. IV, p. 221, Pl. 35, figs. 10-14.

Hall's description.—"Shell gibbous; valves subequally convex, semielliptical or subtriangular; hinge line longer than the width of the shell and prolonged into mucronate extensions, length about half the width of the hinge line. Surface coarsely plicated. Ventral valve regularly convex, arcuate; beak arcuate over a sublinear area of moderate height, extending to the limits of the cardinal line; mesial sinus strongly defined, subangular. Dorsal valve regularly convex, the greatest convexity in the middle and regularly arcuate from beak to base; mesial fold abruptly and strongly elevated, with the summit flattened or grooved; beak incurved, area very narrow. Surface strongly marked by three, four or five abruptly elevated

angular plications on each side of the mesial fold and sinus, leaving a somewhat wide corrugated space at the cardinal angles. The plications bordering the sinus are stronger, more elevated, and continuing distinct quite to the apex. The shell is concentrically marked by strong imbricating lamellose striae, which are abruptly bent backward and much elevated in crossing the plications, giving them a subnodose character. In the bottom of the sinus, these lamellose striae have often a distinct retral bend, with a slight elevation indicating an incipient plication which corresponds with the depression in the mesial fold."

In all of the specimens under observation a distinct retral bend in the striae in the bottom of the sinus is noticeable; two or three of the larger ones have a well developed plication in the bottom of the sinus. The plications on each side of the fold and sinus vary from five to six. The plications sometimes extend almost or quite to the cardinal angles. The specimens vary from eleven-sixteenths of an inch to one and one-third inches in width. The lamellose striae vary from fifteen in the smaller specimens to twenty in the larger.

This shell is very rare in Indiana.

Delthyris consobrina, which is closely related to this species, was included in my list, published in 1899* on the authority of the catalogue of the State Museum. Examination of the specimens labeled *D. consobrina* shows them to belong to another species.

Formation and locality.

Sellersburg beds; Charlestown, Falls of the Ohio.

Delthyris raricosta Conrad.

Pl. IX, fig. 9.

Spirifer raricosta Hall, Pal. N. Y., Vol. IV, p. 192, Pl. 27, figs. 30-34; Pl. 30, figs. 1-9.

Hall's description.—"Shell subquadrate, semicircular or ovate, gibbous; hinge line equaling the width of the shell or often less; cardinal extremities rounded. Surface strongly plicated. Ventral valve most gibbous in the upper half and sloping abruptly to the cardinal angles, which are rarely a little extended and subauriculate; beak much elevated and much incurved over the area which is variable in elevation, sometimes being barely perceptible, while in others it has a width of from one to two lines and is marked longitudinally by a few strong striae. The mesial sinus is a broad rounded depression and reaches with the adjacent plications quite to the apex.

* Bull. Am. Pal., No. 12, p. 60.

Dorsal valve gibbous most convex in the middle, flattened or a little concave toward the cardinal angles. The mesial fold is very prominent and rounded or a little flattened in the middle, regularly arcuate and forming the small beak which is arched over the linear area. Surface marked by from two to four strongly elevated rounded or subangular ribs on each side of the mesial fold and sinus. In one specimen I have seen a fifth plication toward the cardinal angle. The entire shell is covered by strong lamellose or imbricating concentric striae, which are undulated upon the ribs and intermediate depressions. These concentric lines are sometimes quite regularly equidistant, but often crowded and irregular in their distribution and more or less prominent at their edges. There are a series of fine closely arranged radiating striae crossed by the concentric lamellae and in very perfect shells a fimbriate aspect. The surface is usually more or less worn, and only the stronger concentric lamellae are visible; and even these are often partially or entirely obliterated. In some specimens where the shell is well preserved the plications are rounded and not very prominent; while they become more distinct with a subnodose character, on the exfoliation of the shell. The mesial sinus is usually very wide at its base, sometimes equal to half the length of the shell. The proportions of the shell are extremely variable, the length being sometimes greater than the width, while usually the width is somewhat greater than the length; and in some individuals the length and breadth are as two to three. The casts of the ventral valve show a small rostral cavity with short strong dental plates; the muscular area being small, quadrangular and divided through the middle by a distinct septum. The interior of the shell of the ventral valve shows short strong hinge teeth and very short incurving plates below, while the bottom of the cavity is divided by a distinct elevated septum. The dorsal cast shows marks of dental sockets, with strong muscular markings at the apex of the fissure."

This is a very rare species.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown and Falls of the Ohio.

Pentagonia unisulcata (Conrad).

Pl. X, figs. 6, 6a, 6b, 6c, 6d.

Meristella (Pentagonia) unisulcata Hall, Pal. N. Y., 1867, Vol. IV, p. 309, Pl. 50, figs. 18-35.

Hall's description.—"Shell subtrigonal, quadrilateral or sometimes subhexagonal in outline, wider in front with the sides sometimes

sloping from the beak; and in others the hinge line extended nearly straight, and the sides nearly rectangular to it. A wide mesial depression on one side, with prominent elevation on the other. Ventral valve with a broad deep mesial sinus which occupies nearly the whole width of the valve, and is bounded on either side by an angular elevation which extends from the beak to the baso-lateral angles. The portion of the valve outside of the limitation by the sinus is abruptly inflected upwards and often nearly at right angles; the umbo is prominent and the beak is incurved over the umbo of the dorsal valve. Dorsal valve gibbous in the middle; the centre occupied by a prominent mesial fold, from which the surface slopes abruptly to the lateral angles, becoming more or less concave within the lateral and cardino-lateral margins. The mesial fold is marked along the center by a single deep groove, which extends to the beak of the valve. Surface marked by fine concentric striae, and sometimes by strong imbricating folds. In well preserved surfaces the striae and undulations are bent backwards in the middle of the mesial sinus indicating a mode of growth in the shell corresponding to the sinus in the mesial fold of the opposite valve. There are also slight indications of interrupted radiating striae. In the specimens from the Hamilton group there are appearances of faint undefined continuous striae. The specimens from the limestone are for the most part exfoliated, or have the shells silicified, by which the finer markings are obliterated. The interior of the ventral valve shows a perforation in the beak opening below into an angular space which has been occupied by the beak of the dorsal valve and thence communicating with the main cavity of the valve. The base of the fissure is margined on each side by a strong tooth on each side, which extends in strong dental plates to the bottom of the cavity, and these are often continued in a thickened ridge bordering the muscular impression. The imprints of the adductor muscles are opposite the bases of the dental plates, and below and on either side are the imprints of the broad divaricator muscles. In the dorsal valve the cardinal process is broad and strong, the crural bases somewhat widely diverging and the center abruptly depressed; the teeth sockets are long and supported by strong lamellar callosities which extend along the inner side of the valve nearly parallel to the exterior margin. The muscular imprints are divided by a low distinct septum."

Variation in this species occurs chiefly in connection with three characters,—the mesial fold, the short oblique folds near the beak on the dorsal valve and the angular ridges bounding the mesial sinus. The latter are always well developed and either obtusely or sharply

angular near the beak; when these ridges are obtusely angular near the beak they usually fade out before reaching half way to the front into the gently rounded sides of the ventral valve; in some specimens, however, they continue from the beak to the front as sharply angular elevations. The groove marking the center of the mesial fold varies from a well marked depression which extends from the beak to the front of the shell, to a shallow groove noticeable only at the beak. A series of shells from Mr. Green's collection shows this groove extending from beak to front in some specimens, and gradually retreating toward the beak in others until only a trace of it is preserved at the beak, the remainder of the fold being rounded on the top. In some specimens there is a short well marked oblique fold on each side the beak on the dorsal valve. In one specimen there is a second fold slightly developed. A series of shells arranged with reference to the development of this fold shows it growing gradually less distinct until it is entirely absent or barely noticeable.

A study of a series of these shells shows that the variations of the three characters above described are closely correllated. The cardinal folds, the angular ridges of the ventral valve, and the groove on the mesial fold have about the same relative development on each individual.

This is a rather rare species.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown and Falls of the Ohio and Newbern.

PENTAMERELLA.

A. Length exceeding the width considerably. — *P. thusneldia.*

AA. Length less than the width or exceeding it but slightly.

  b. Plications numerous and usually bifurcated. — *P. arata.*

  bb. Plications few and simple. — *P. pavilionensis.*

Pentamerella pavilionensis Hall.

Pl. VII, figs. 1, 1a.

P. pavilionensis Hall, Pal. N. Y., 1867, Vol. IV, p. 377, Pl. 58, figs. 28-39.

Hall's description.—"Shell ventricose broadly ovate, often wider than long, more or less gibbous and arcuate in old shells. Ventral valve gibbous or ventricose above, becoming depressed in the middle into a broad shallow undefined sinus, which scarcely reaches to the beak, and sometimes not much above the middle, and is produced in front; sides abruptly curving to the margin; beak incurved, obtuse,

arching from the broad fissure; cardinal line extending for more than half the width of the shell. The space above on each side of the fissure is concave and wrinkled. Dorsal valve gibbous in the middle, somewhat regularly curving to the sides and front; sides abruptly curving to the margin; beak incurved, obtuse, arching from the broad fissure; cardinal line extending more than half the width of the shell. The space above on each side the fissure is concave and wrinkled. Dorsal valve gibbous in the middle, somewhat regularly curving to the sides and front; mesial fold defined below the middle of the valve. Surface plicated, the plications rounded or subangular, becoming obsolete towards the beak, and prominent below the middle; of these there are two or three in the mesial sinus, and usually about four on the mesial fold, with three, four or five on either side. The plications are crossed by fine concentric striae of growth, which, at irregular intervals, are crowded into squamose imbricating lines. The entire surface is finely papillose or punctate and when well preserved might be mistaken for a punctate shell. The substance of the shell is lamellose-prismatic and brittle. The interior of the ventral valve shows a broad short and deep spoon-shaped pit, the extremity of which is bent abruptly to the dorsal side. The septum supporting the conjoined lamellae extends from one-third to one-half the length of the valve, and in some examples may extend still farther toward the anterior margin. The interior of the dorsal valve is not fully known."

The specimens in Mr. Green's collection from the Falls of the Ohio show considerable variation. One specimen has nine or ten plications on each valve, while in some specimens only the three or four plications occupying the fold and sinus are developed. All of the plications fade out entirely or become very indistinct before reaching the cardinal line. In one shell the umbo is twisted to one side giving the distorted appearance so common in *Cyrtina hamiltonensis*. This species is common.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown and Falls of the Ohio, Bunker Hill, Pipe Creek Falls, and Little Rock Creek, Cass County.

Pentamerella thusnelda Nettleroth.

P. thusnelda Nett., Ky. Foss. Shells, p. 51, Pl. 31, figs. 26, 27, 28.

Nettleroth's original description.—"Shell of medium size, ovoid or subquadrate; cardinal extremities rounded, forming in the beak of the dorsal valve an angle of a little more than sixty degrees; length exceeding the width considerably, giving to the shell an elongate somewhat slender appearance. Ventral valve ventricose, even gibbous; convexity regular from beak to front, and also transversely; greatest convexity a little above the middle of the valve; mesial sinus indicated by two very strong plications, and by a wide and deep groove on each side of them; the summit of these plications drops not at all, or at least very slightly, at the very front of the valve, below the regular surface; the two prominent grooves extend almost to the beak forming on the umbo only one rib, which separates into two plications in front of the beak; these mesial ribs are considerably prolonged in front, producing a subquadrilateral extension, beak is prominent and incurved, cardinal area large, extending to the extremities and bounded by a well marked regularly curved line of demarcation; fissure of moderate size but partly closed by the beaks of both valves. Dorsal valve depressed convex, curved slightly in the upper half of the valve; lateral partitions of lower half almost flat, mesial fold formed by three strong plications, which are united into one simple elevation on the umbo, where it is only faintly visible; below the umbo the three mesial ribs separate and extend to a little beyond the front, where they are considerably elevated; beak moderate and incurved into the foramen of the other valve, cardinal area only linear. Surface marked by about twelve subangular plications, of which those of the mesial depression and elevation are considerably stronger than those on the lateral slopes; the lateral ribs on the dorsal valve are single and of equal size; those on the ventral valve increase by bifurcation, and those nearest to the mesial furrows appear to be stronger than the more lateral ones."

Nettleroth reports this species to be rare, only two specimens being known.

Formation and locality.

Jeffersonville limestone ("Corniferous"); Falls of the Ohio.

Pentamerella arata (Conrad).

Pl. VII, fig. 2.

P. arata Hall, Pal. N. Y., 1867, Vol. IV, p. 375, Pl. 58, figs. 1-21.

Hall's description.—"Shell ovate, more or less convex or gibbous, becoming arcuate ovoid in old shells; the width greater or less than the length; hinge line variable. Ventral valve gibbous and somewhat regularly convex in the young shells, becoming ventricose in old shells, with a mesial sinus which is more or less developed. In old shells the form is extremely arcuate and the beak strongly incurved; in shells of medium size the beak is obtuse, limiting the apex of the triangular fissure. There is a narrow area bordering the fissure and the space on either side between the hinge line and its apex is often flattened and sometimes distinctly limited by a faint elevation; fissure large and nearly covered by the beak of the opposite valve. Dorsal valve in young shells more or less convex, and sometimes gibbous in the upper part, and often moderately convex in older shells; mesial fold usually well defined in the lower half of the valve, sometimes reaching nearly to the apex; in young shells there is rarely a short sinus in place of the mesial elevation. Surface plicated by rounded or angular plications, which sometimes reach nearly or quite to the beak but are often only developed below the first third of the length; plications usually bifurcated; the bifurcations irregular or unequal. The interior of the ventral valve has an elongate spoon-shaped pit, the inner extremity of which is free for a considerable extent and the upper part supported on the central septum which usually extends less than half the length of the shell from the apex. In the dorsal valve the crura or lamellae are joined at their bases, making a V-shaped trough or pit, which is attached to the valve in its upper part and continues sessile for about one-half the length of the shell."

Hall states that this species may be distinguished from *P. pavilionensis* by its greater number of plications which are more or less angular and usually bifurcate.

Only three or four specimens in a collection of about eighty Pentamerellas show any bifurcating striae. A few specimens clearly correspond to the *P. arata* type in their abundant and angular plications, but the *pavilionensis* type generally predominates in numbers.

Formation and locality.

Jeffersonville limestone; Bunker Hill, Cass County and Falls of the Ohio.

STROPHEODONTA.

A. Shell nearly flat, striae rather fine. *S. perplana.*
AA. Shell arched with some or all of the striae coarse.
  b. Shell very large, frequently two inches or more in width. *S. concava.*
  bb. Shell small or of moderate size.
    c. Surface marked by distant elevated striae and the interspaces occupied by very fine striae.
      d. Shell usually more than an inch in width, striae less regular on the ventral than on the dorsal valve. *S. inequiradiata.*
      dd. Shell usually less than one inch in width. Striae on the ventral and dorsal valves similar. *S. inequistriata.*
    cc. Surface marked by bifurcating coarse striae.
      e. Shell small, striae few and very coarse. *S. plicata.*
      ee. Shell of moderate size, striae numerous, and usually rather fine toward the margin. *S. demissa.*

Stropheodonta demissa (Conrad).

S. demissa Hall, Pal. N. Y., 1867, Vol. IV, p. 101, Pl. 11, figs. 14-17.

Hall's description.—"Shell semielliptical, usually wider than high, length and breadth often nearly equal; hinge line equaling or greater than the width of the shell below, abruptly contracted beneath the extremities, which are often auriculate; in some specimens the sides are nearly straight, and parellel for more than half the length of the shell. Ventral valve regularly convex, often gibbous; greatest elevation nearly central, and sometimes subangulated along the middle; umbo small and prominent with the apex slightly incurved and extending beyond the plane of the area. Surface a little concave toward the cardinal angles which are slightly deflected. Dorsal valve moderately concave, rarely following the convexity of the opposite valve; sometimes an undefined median depression extends from beneath the apex to the front of the shell. Area of ventral valve variable, usually of moderate width, from 8/100 to 12/100 of an inch wide in the center, having a low triangular outline, concave in the middle, and for a considerable distance on each side of the beak, strongly striated transversely and more faintly longitudinally, sometimes marked along the middle by a subangular elevation; inner margin crenulated for nearly its entire length. There is no foramen but sometimes a smooth triangular space beneath the beak. Dorsal area narrow and usually linear, sometimes wider and

sometimes narrower in the middle, and the margin for a short space free from crenulations. The planes of the two areas are inclined so as to sometimes give less than a right angle between them, but generally a greater angle, and along the middle the two are often nearly in the same plane. Surface marked by numerous crowded striae, about nine or ten of which are much stronger and more elevated on the umbo of the ventral valve, with finer ones coming in between and on either side; striae frequently increasing by intercalation and bifurcation, until they become very numerous and much finer at the margin. On the dorsal valve the striae are similar to those on the ventral valve. In well preserved specimens fine concentric striae cover the entire surface, but the greater number of specimens do not preserve these markings. The coarser striae are sometimes seen separated on the middle of the shell, each one presenting the appearance of a fascicle of striae, which spreading, cover the lower part of the shell with extremely crowded striae. The interior of the ventral valve and casts of the same show a large flabelliform divaricator muscular impression, which is somewhat widely separated in front, and each division distinctly lobed. The occlusor muscular impressions occupy a semielliptical space on each side of a narrow central depression, the marking on either side being double in well preserved specimens. The upper extremities of this impression are close under the arch of the umbo, and separated by a smooth space from the divaricator impressions. Beyond the muscular impressions the interior surface is pustulose, the points being more prominent just without their limits; beyond which the course of the vascular impressions can be distinctly traced. In the dorsal valve the anterior and posterior occlusor muscular impressions are very conspicuous and deeply marked and often limited by an elevated ridge, a narrow longitudinal ridge dividing the two pairs. On each side and below the muscular impressions the surface is marked by small pustules or tubercles; and beyond these the surface is minutely pustulose, the muscular impressions becoming distinct toward the margin. The cardinal process is divided from the base, the divisions strongly diverging."

The specimens at hand vary considerably in the convexity of the dorsal valve; in some specimens it is deeply arched while in others it is nearly flat. Three types of surface markings which merge into each other in a large collection are distinguishable in this species; shells with not very coarse striae which are of uniform size from the beaks to the margin; shells with very coarse striae near the beaks, each of which splits into a bundle of fine striae toward the middle

of the shell; and shells with a few coarse and sometimes very indistinct striae near the beaks which fade out before reaching the middle of the shell, leaving the greater part of the shell entirely bare of striae, or marked by very faint striae.

This is one of the most abundant species in the Indiana Devonian.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; throughout the Devonian area.

Stropheodonta plicata Hall.

Pl. VI, fig. 2.

S. plicata Hall, 13th Rep. N. Y. State Cab. Nat. Hist., 1860, p. 90.

The character of this shell is sufficiently indicated by the figures. It seems to differ from S. dimissa only in the stronger plications. It should probably be considered a well marked variety of that species.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Stropheodonta perplana (Conrad).

Pl. V, figs. 3-7.

S. perplana Hall, Pal. N. Y., 1867, Vol. IV, pp. 92-98, Pl. 11, fig. 22; Pl. 12, figs. 13-15; Pl. 17, fig. 1.

Hall's description, in part.—"Shell semielliptical; the length varying from two-thirds to three-fourths the width, which is from half an inch to two inches; slightly concavo-convex, and often nearly flat; hinge line equaling or often a little greater than the width of the shell below; but the sides are frequently nearly straight for half their length, and the front broadly rounded with the margin attenuate. Ventral valve very little convex, the greatest convexity above the middle of its length, with frequently a few obscure concentric wrinkles near the apex and sometimes upon the body of the shell; apex scarcely rising above the hinge line, and slightly incurved. Dorsal valve gently concave and often nearly flat. Area of the ventral valve usually less than a line in width, inclined to an angle of 40 degrees to 50 degrees to the plane of the margins and curved in the upper part, vertically striated in its whole extent and crenulate on the inner margin; sometimes a flat triangular space in place of a foramen, with a narrow callosity in the middle, but this feature is not always observable. Area of the dorsal valve about half as wide as that of the ventral, gently curved outward, leaving an angle between the two of more than 90 degrees; the center is marked by a

narrow callosity or an impressed space. Surface covered by fine subequal striae, those of the ventral valve being the finer, extremely sharp and often gently undulating, increasing both by bifurcation and intercalation and crossed by fine even concentric striae. In some specimens the longitudinal striae rise at frequent intervals into minute granules, evidently the bases of minute spines, which have covered the surface of the ventral valve. Very rarely there is some interruption in the regularity of the striae, apparently owing to an injury which has caused the concentric striae to curve toward that point, and the radiating striae to converge, making a kind of seam or cicatrix."

The common form of this species corresponds to the above description. There is a variety of the species, however, which has the striae arranged in fascicles of from three to six fine ones between stronger and more elevated striae.

This is a common species in northern and southern Indiana.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Little Rock Creek, Cass County and from Shelby County to the Ohio in southern Indiana.

Stropheodonta concava Hall.

Pl. V, figs. 1, 1a, 2; Pl. VI, fig. 1.

S. concava Hall, Pal. N. Y., Vol. IV, 1867, p. 96, Pl. 16, figs. 1a-1h.

Hall's description.—"Shell large, from two to three and a half inches wide on the hinge line, concavo-convex or subhemispheric, broadly semielliptical or subcircular, sometimes subtriangular from becoming narrowed in front. The proportions vary from nearly equal length and breadth to a width one-fourth to one-third greater. The hinge extremities salient, but often rounded. Ventral valve varying from moderately to extremely convex, and becoming gibbous in the middle, rounded upon the umbo and little elevated above the hinge line, with beak small and scarcely incurved in some specimens, the centre of the valve is elevated in a median ridge. Dorsal valve usually almost flat or slightly concave in the upper and central portions, becoming suddenly deflected toward the margin; in some specimens regularly concave. Area of the ventral valve nearly on a plane with the axis of the shell about a line in width, narrowing toward the extremities, vertically striated with the margin crenulated for more than half the distance from the center to the extremities. Area of the dorsal valve almost rectangular to that of the ventral valve, very narrow and nearly linear throughout; sometimes narrower

in the middle striate and crenulate in the opposite valve; with a small smooth triangular space beneath the apex. The surface of the ventral valve is marked by sharply elevated, strongly crenulated striae, between which are sometimes one or two less elevated striae similarly crenulated and still finer striae between the latter. In other specimens there are wider spaces of finer equal striae between the stronger ones; and in still other examples, the striae are nearly all strong and sharply elevated, with few finer ones, which soon rise to the strength of the others. Close undulating concentric striae cover the whole surface. The dorsal valve is marked by distant sharp elevated striae, between which there are from three to six and rarely ten finer striae, which are very finely crenulated by concentric striae. In some specimens the ventral valve is marked by an irregular fold or ridge down the middle, and there are sometimes a few incipient plications on one or both sides towards the margin of the shell. These plications likewise affect the dorsal valve. The interior of the valves is finely pustulose. The divaricator muscular impressions of the ventral valve are large and spreading, about as wide as long, extending nearly half the length of the valve and deeply striate; while the occlusor impressions are elongate-ovate or cordiform and strongly marked. The muscular impressions of the dorsal valve are strong and divided above by a rounded ridge which supports the strong bifurcate cardinal process, each division of which is bilobed, and the surface roughened for the muscular attachment."

The large size of this shell readily distinguishes mature specimens from any other species of the genus. Each of the three specimens from near Pipe Creek Falls exceeds three inches in width. One of these measures in the widest part 3¾ inches and 2⅞ inches in length. Many mature shells, however, do not reach this size.

This species is rather common.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Pipe Creek Falls, Little Rock Creek, Cass County, Charlestown, Sellersburg and Falls of the Ohio.

Stropheodonta hemispherica Hall.

There seems to be no clearly defined difference between *S. concava* and *S. hemispherica* as defined by Hall. The specimens heretofore referred by the writer* to the latter species are probably varieties of *S. concava.*

* Bull. Am. Pal., No. 12, p. 68.

Stropheodonta inequistriata (Conrad).

Pl. IV, figs. 12, 13.

S. inequistriata Hall, Pal. N. Y., 1867, Vol. IV, p. 106, Pl. 12, figs. 6-8; Pl. 18, fig. 2.

Hall's description.—"Shell semioval or semicircular in outline; hinge line extended beyond the width of the shell below; extremities acute, sometimes auriculate. Rarely the sides are nearly straight below the auriculate extremities, and the basal curve rather straightened on each side and produced in a subnasute extension in the middle. Ventral valve usually convex and often gibbous in the middle and abruptly arched toward the hinge line, depressed-convex on the disc the margin toward the front more abruptly curving; sometimes gently sloping towards the front and abruptly constricted on the sides below the cardinal extremities, which are deflected toward the ventral side; the beak is small scarcely prominent on the hinge line. Dorsal valve moderately concave, often more deeply concave; sometimes moderately concave in the upper and middle part, and suddenly deflected toward the front. Area of the ventral valve narrow linear, extending to the extremities of the hinge line, striate vertically, with the inner margins crenulate from one-half to two-thirds the length from the beak to the extremities; foramen none; a slight linear elevation extends across the area. Dorsal area scarcely more than half as wide as the ventral area, and, in every perfect specimen having a narrow elevated ridge crossing it in continuation of that of the opposite valve. Surface of the entire shell marked by slender elevated striae, which are increased by interstitial additions; the interspaces occupied by much finer closely arranged striae, which are scarcely visible to the naked eye, and crossed by fine concentric striae. In the interior of the ventral valve, the occlusor muscular impressions occupy a narrow subquadrangular elevated space just beneath the apex; while the divaricator muscular imprints occupy a short broad space on each side and are limited by nearly vertical or slightly converging ridges which have in some degree the appearance of dental lamellae; within the limits of these ridges the muscular imprints are not strongly marked. In the dorsal valve the posterior occlusor imprints are broad and extending far toward the cardinal line and often limited by a low pustulose ridge; the anterior impressions are small and narrow, separated by a narrow mesial ridge and margined by diverging elevated ridges, which above the impression are united in the mesial ridge from which proceeds the bifurcating cardinal process; the divisions of this process are broad and some-

what flattened vertically or a little obliquely and sometimes grooved on the inner side and distinctly bilobate at the cardinal extremities. The condition of the muscular imprints is subject to considerable variation; for in some specimens those of the interior occlusors are raised in two prominent processes to a height greater than the enclosing ridges, and sometimes the imprints remain depressed, and the enclosing ridges are extremely elevated, arching over and nearly enclosing the muscular area. Just without the muscular areas, in both valves, the interior surface is rather strongly pustulose and beyond this it is finely pustulose in lines corresponding to the external striae; while the dorsal valve more often than the ventral, is marked by strong vascular impressions."

Most of the specimens of this species have the ventral valve highly arched. Those from northern Indiana seldom exceed three-quarters of an inch in width. Sharp elevated striae with interspaces containing from six to fifteen very fine striae mark the surface of both valves.

This is a common species in northern Indiana but less common in southern Indiana.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Bunker Hill, Pipe Creek Falls, Charlestown and Falls of the Ohio.

RHIPIDOMELLA.

A. Beak of ventral valve extending beyond the beak of dorsal valve; dorsal valve usually without sinus. *R. livia.*

AA. Beak of ventral valve not extending beyond the beak of dorsal valve, or but slightly.

- b. Shell narrow toward the beaks, sides sloping from them in nearly straight lines to near the middle of shell; dorsal valve very gibbous. *R. leucosia.*
- bb. Shell wide toward the front sides near the beaks rounded, dorsal valve slightly gibbous. *R. vanuxemi.*

Rhipidomella vanuxemi Hall.

Pl. III, fig. 14; Pl. IV, figs. 1, 1a, 2, 3, 3a.

O. vanuxemi Hall, Pal. N. Y., 1867, Vol. IV, p. 47, Pl. 5, fig. 6; Pl. 6, fig. 3.

Hall's description.—"Shell subcircular or transversely suboval compressed; hinge line very short; margins of the valves crenulated within from the external striae; interior minutely punctate. Dorsal valve convex; beak scarcely distinct from the cardinal border, not incurved; cardinal process prominent; area flat or slightly inclined

to the ventral area and about two-thirds as wide. Ventral valve nearly flat or a little concave toward the front, moderately convex in the umbonal region; beak small, extending little beyond the opposite beak, arched and rarely incurved over the area; area very small, less than half the greatest breadth of the shell, arcuate; foramen comparatively large, triangular, and partly filled by the cardinal process of the other valve; teeth prominent. Surface marked by fine, closely arranged radiating tubular striae, which are perforate at intervals, increasing both by implantation and bifurcation, and are crossed by very fine indistinct concentric striae, and, at greater intervals, by more distinct concentric imbricating lines of growth; entire surface granulate or punctate, under a magnifier. Striae from twelve to sixteen in the space of two lines near the beak, and from seven to nine in the same interval near the margin. The interior of the dorsal valve shows a strong cardinal process, which is continued in a prominent rounded median ridge for half the length of the shell, where it sometimes divides, or gradually becomes obsolete; there are sometimes visible low transverse ridges which divide the muscular impression. The crural processes are prominent and sustained below by strong oblique ridges. In the interior of young specimens, the marks of the external striae visible nearly or quite to the muscular impressions; while in older specimens these marks extend little beyond the margin. The interior of the ventral valve is marked by a large flabelliform muscular impression which reaches from one-half to two-thirds the length of the shell. The central or adductor impression is sometimes simple and sometimes longitudinally divided by a slight median ridge which is stronger below. In the older shells the ovarian spaces are pustulose. The dental lamellae are strong and divergent, supported below by the ridge which margins the muscular impression. Vascular impressions are rarely seen extending beyond the muscular area. Under a lens the interior surface is distinctly punctate. In all well preserved specimens the exterior shows minute tubular openings in the striae; and when the striae are much worn, these also are seen to be tubular; while a farther wearing of the surface shows more distinctly the minutely punctate character of the shell."

This species is very abundant at many localities. The specimens correspond closely to the above description.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Bunker Hill, Little Rock Creek, Cass County, North Vernon, Charlestown, Lexington and Falls of the Ohio.

Rhipidomella leucosia Hall.

Pl. III, figs. 12, 13, 13a.

Orthis leucosia Hall, Pal. N. Y., IV, 1867, pp. 48, 63, Pl. 7, fig. 4; Pl. 8, figs. 9, 10.

This species is so closely related to *R. vanuxemi* that it is, as suggested by Hall, probably only a variety of that species. A few specimens in Mr. Green's collection correspond to the description and figure of *R. leucosia*. They differ from *R. vanuxemi* in their more ovate form, more gibbous dorsal valve and in the less rounded extremities of the cardinal line; the margin of the shell from the beak to near the middle forms a nearly straight line. In two specimens the length and greatest breadth of the shell are equal; in the others the width exceeds the length very slightly. This species is rare.

Formation and locality.

Sellersburg beds; Charlestown.

Rhipodomella livia (Billings?).

Pl. IV, fig. 4.

Orthis livia Billings, Can. Journ. of Industry, Sci. and Art, No. 27, p. 269, 1860.

Billings' original description.—"Shell suborbicular or subquadrate, length about eight-ninths of the width; greatest width usually a little in front of the middle; length of hinge line one-half to two-thirds the width of the shell; cardinal extremities rounded; sides in most specimens somewhat straight, often sufficiently curved to give a circular aspect to the shell; front angles obtusely rounded, front margin in general broadly convex, sometimes, in a small central portion nearly straight. Dorsal valve of medium convexity, most elevated about the middle; the outline forming an uniform arch from depressed beak to front margin; slope from umbo to cardinal angles gently concave; sometimes a barely perceptible mesial depression, commencing on a point at the beak, and becoming obsolete at one-half or two-thirds the length; area small, lying in the plane of the lateral margins; beak minute, forming a small triangular projection rising scarcely one-fourth of a line above the edge of the area. Ventral valve moderately convex, most elevated at between one-fourth and one-third the length from the beak, thence descending with a flat or gently concave slope to the lateral margins, with a somewhat concave one to the front, and also to the hinge line and cardinal angles. The concavity toward the front is not found in all speci-

mens; some shells have basal portions either flat or slightly convex. The ventral umbo is small and neatly defined; beak small pointed and somewhat incurved, but scarcely overhanging edge of the area; area triangular and somewhat larger than the dorsal one. Foramen not observed. Surface covered with small subangular radiating ridges or striae of nearly uniform size, from eight to ten in the width of three lines, increasing by bifurcation, strongly curved outward on the lateral part of shell; the interspaces subangular and equal in size with the striae. In perfect specimens very fine concentric sub-lamellose striae are visible, seven ar eight to one line. In certain conditions of preservation, also, the radiating striae are seen to be subtubular, and exhibit numerous small oval or circular openings on their edges, each about the eighth or tenth of a line in width and from one-fourth to two-thirds of a line distant from each other."

A specimen in the State Museum which is here figured, is doubtfully referred to this species.

Formation and locality.

Sellersburg beds; Clark County.

Rhipidomella goodwini Nettleroth.

R. goodwini Nett., Ky. Foss. Shells, 1889, p. 39, Pl. 17, figs. 30-31.

Nettleroth's original description.—"Shell small, subcircular or subquadrate; moderately convex in both valves; hinge line short, equal or less than half the width of the shell; cardinal extremities rounded; lateral margins almost straight or very slightly curved; they diverge toward the base in consequence of which greatest width of shell is close to base or front; the basal margin is broadly curved, with its central portion either straight or slightly inflected. Ventral valve is somewhat more convex in its umbonal region than dorsal, but in its basal half it is the reverse. Its greatest convexity is just below the umbo, from where it slopes in a very gentle curve to lateral and basal margins, but more rapidly, even almost abruptly to the cardinal lines; umbo moderate, beak a little elevated above opposite valve, sharp pointed and slightly arched, but not incurved. Cardinal area short but comparatively high, limited by sharp margins and divided by an open triangular foramen, which is partly closed at its base by the cardinal process of the dorsal valve. Dorsal valve moderately convex; point of greatest convexity a little above middle of valve, from where it slopes to all the margins and to the beak, giving the valve over its whole surface an even convexity, with the exception of a narrow strip in the middle, which extends from beak to base, and

which is slightly depressed. This mesial depression is deepest in its middle portion; it is only faintly marked upon the umbo, and it becomes shallower but wider toward the base. The surface of both valves is ornamented by fine thread-like radiating striae which increase in number, partly by bifurcation, but mostly by intercalation; these radii are crossed by several concentric lines of growth, which become more numerous toward the basal margin. In regard to size the specimen illustrated on plate 17, figures 30, 31 and 32, is of about the average size, though a few specimens have been found which are considerably larger."

The specimen figured by Nettleroth is a half inch in width.

The above description agrees perfectly with shells which the writer considers to be immature specimens of *R. vanuxemi*. It seems probable that Mr. Nettleroth's species is based on young specimens of *R. vanuxemi*.

Formation and locality.

"Hamilton"; Falls of the Ohio.

Schizophoria striatula (Schlotheim).

Pl. III, figs. 11, 11a.

Orthis impressa Hall, Pal. N. Y., 1867, Vol. IV, p. 60, Pl. 8, figs. 11-19.

Hall's description.—"Shell rotund. Dorsal valve very gibbous, wider than long, sinuate in front; hinge line about two-thirds the width of the shell. Ventral valve moderately convex at the sides, somewhat flattened on the umbo, with a broad undefined sinus which becomes deeper toward the front, the margin of the shell being sometimes abruptly incurved at the beak. The surface is finely and evenly striated and the texture of the shell is minutely punctate. The cast of the dorsal valve shows strong, somewhat quadrilobate, muscular impressions, limited by strong and widely diverging socket plates, with the vascular impressions somewhat narrow and extending below it to the margin of the shell. The surface of the cast preserves fine even striae. The cast of the ventral valve is broadly sinuate in the middle below with a triangular or subovate deeply bilobed muscular impression, which is subject to considerable variation in form and proportions."

This shell is frequently found associated with *Rhipidomella vanuxemi* but is very much less common than that species.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Lexington, Paris Crossing, Lancaster, Sellersburg, Charlestown and Falls of the Ohio.

MARTINIA.

A. Anterior margin of shell crenulated by weak plications.

M. williamsi n. sp.

AA. Anterior margin not crenulated, surface without plications.

M. subumbona.

Martinia williamsi n. sp.

Pl. XI, figs. 5, 5a, 5b.

Shell small; length greater than width, cardinal angles rounded, rather ventricose toward the middle; hinge line very short, length of cardinal area exceeding its height about one-half. Ventral valve more gibbous than dorsal, beak slightly incurved over the high fissure; marked toward the front by a very shallow sinus which is barely perceptible in most specimens. Two or three weak plications crenulate the margin of the shell on each side of the sinus; surface marked by fine concentric striae. Dorsal valve marked by a broad, poorly defined fold towards the front, with two or three faint plications on each side near the anterior margin. Fine concentric striae cover the surface. A slight linguiform projection usually characterizes the anterior margin of the shell.

This species is rather common where discovered but it has not been found at any other locality.

Formation and locality.

Geneva limestone; Hope.

Martinia subumbona (Hall).

Pl. XI, figs. 3, 3a.

Spirifer subumbona Hall, Pal. N. Y., 1867, Vol. IV, p. 234, Pl. 23, figs. 22-30.

Hall's description.—"Shell small, more or less gibbous or ventricose; cardinal extremities rounded; surface smooth or finely striated concentrically. Ventral valve ventricose in the middle, regularly curving toward the basal and lateral margins; umbo much elevated above the opposite valve, and beak abruptly incurved over the high area, which has its lateral margins rounded or rarely defined, and sloping toward but not reaching the cardinal extremities; more or less arcuate, and the elevation apparently variable. The foramen is higher than wide and open to the apex in all the specimens observed. There is usually a narrow but not always distinct mesial sinus reaching from the apex to the base of the valve, where it becomes wider but without defined limits. Dorsal valve less gibbous than the ventral, somewhat regularly convex in the middle, and curving toward the front and baso-lateral margins, a little depressed or flattened

towards the abruptly rounded cardinal extremities; umbo slightly elevated above the hinge line; area linear. There is often a faint impressed line extending from the beak to the base of the valve. Surface marked by fine concentric lines of growth which are sometimes crowded into imbricating folds toward the front of the shell. In partially exfoliated specimens the surface is finely and distinctly punctated, as if in its original condition it had been covered by closely arranged spinules. The texture of the shell is fibrous yet differing from the fibrous texture of ordinary Spirifers."

All of the specimens referred to this species are from a single locality where they are very abundant. They differ from Hall's figures in having the beak of the ventral valve more sharply incurved over the area. In some specimens it almost or quite touches the beak of the dorsal valve, and the area is very narrow. The ventral sinus mentioned by Hall is noticeable only on one or two specimens, where it is represented by the faintest kind of a depression. Average specimens measure ⅜ of an inch in width; one specimen has a width of ½ inch. The shells have the length and the greatest width equal.

This shell resembles in some respects *Ambocaelia umbonata*. It is, however, about twice the size ordinarily attained by *A. umbonata* in southern Indiana; the dorsal valve is much more concave than in that species, and the beak of the ventral valve less elevated; it is usually incurved until it lies in the plane marking the contact of the two valves.

Formation and locality.

Sellersburg beds; Little Rock Creek, Cass County.

Nucleospira concinna Hall.

Pl. XI, fig. 7.

N. concinna Hall, Pal. N. Y., 1867, Vol. IV, p. 279, Pl. 45, figs. 33-57.

Hall's description.—"Shell depressed, subspheroidal, nearly circular in outline, the width being usually a little greater than the length; valves subequal. Ventral valve regularly convex, the greatest convexity a little above the middle, and curving regularly to the sides and front; umbo prominent, the beak neatly pointed and incurved over the apex of the dorsal valve, leaving a space between, which sometimes exposes a narrow area. There is usually a narrow depressed line from the beak to the base of the valve; but this is sometimes partially absent, or so faint as not to be readily observed. Dorsal valve regularly convex sometimes gibbous, becoming a little

depressed towards the base, the greatest convexity being a little above the center; there is usually a depressed line along the middle of the valve. The hinge line is about one-third, and sometimes half as long as the width of the shell. Surface usually smooth or very finely papillose; but in its perfect condition it is covered by numerous fine setae which are matted together and the interstices being filled with clay, it has a rough appearance; while under a lens, these setae give a finely striate aspect. Beneath the fine papillose surface the texture of the shell is minutely punctate. The interior of the ventral valve presents beneath the beak a low depressed area, or false area which is bordered on each side by a strong tooth. The muscular area is somewhat broad, flabelliform, with the margin lobed; the occlusor imprints in the center are strongly marked elongate oval spots, and there is a low median crest which often extends to near the front of the shell. In the dorsal valve there is a strong wide cardinal process, the inner surface of which is mainly occupied by a broad oval pad for the muscular attachment extending in a narrow callosity into the cavity below. The teeth sockets are deep and margined by a strong callosity which forms the base of the process; and from thence proceed the crura and the slender spiral arms, which make about eleven or twelve turns in the larger individuals. The muscular area is narrow, well defined and lobed below; while the inner portions marked by the occlusor muscles are two sublinear spots. A slender crest extends along the middle of the impression. The interior of the shell is somewhat pustulose."

The fine setae which belong to perfect specimens are seldom preserved. The shell is frequently marked by two or more strong lines of growth. This species is not very common.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown and Falls of the Ohio.

PRODUCTELLA.

A. Surface of ventral valve marked by numerous spines or spine bases, frequently sixty or more. *P. spinulicosta.*

AA. Surface of ventral valve marked by a few isolated spines. *P. semiglobosa.*

Productella spinulicosta Hall.

Pl. VI, figs. 9, 9a.

P. subaculeata Hall, Pal. N. Y., 1867, Vol. IV, pp. 54-160, Pl. 23, figs. 4-5, 25-34.

Hall's description.—"Ventral valve gibbous, length and breadth about as seven to eight; hinge extremities angulated, and the margins

being contracted a little below from small ears, while below this contraction the sides are regularly curved and the front is broadly rounded. The umbo is considerably elevated above the hinge line and the apex incurved. Surface marked by closely arranged concentric striae and studded with slender rounded spines. On the upper part of the shell and on the ears these spines are round at the base, and rise directly from the surface. On the middle and lower part of the valve there is a slight elevation of the surface a little above the base of the spine, but not a defined ridge. The number of spines on the individual figured has been sixty or more."

The dorsal valve appears to have been almost if not entirely destitute of spines. Some of the specimens in Mr. Green's collection which have spines $\frac{3}{8}$ of an inch in length on the ventral valve show no traces of spines on the dorsal valve.

Some of the specimens from the lower Devonian of northern Indiana have pretty well defined plications on the ventral valve. A small variety of this shell which does not usually exceed one-fourth of an inch in width was found abundant at one locality in the upper Devonian of northern Indiana.

This shell is very abundant at many localities in northern Indiana but less common in southern Indiana.

Formation and locality.

Jeffersonville limestone and Sellersburg beds; Bunker Hill, Pipe Creek Falls, Little Rock Creek, Cass County, Shelby County, North Vernon, Paris Crossing, Kent and Falls of the Ohio.

Productella semiglobosa Nettleroth.

P. semiglobosa Nett., Ky. Foss. Shells, 1887, p. 70, Pl. 26, fig. 7.

Nettleroth's original description.—"Shell of medium size, semiglobose or subcircular; hinge line somewhat shorter than greatest width of shell; cardinal extremities rounded. Ventral valve very gibbous, regularly curved from the umbo to the front, and also transversely; umbo only moderately elevated above surrounding surface; beak incurved upon the hinge line, not overlapping it into dorsal valve. Width and length of shell about equal but sometimes the width exceeding the length. Dorsal valve apparently deeply concave but its other characters are not known. Surface does not show any markings except the stumps of a few isolated spines placed at irregular intervals; the figure 7 on plate 26 shows about twice as many as in reality exist. I am unable to identify it with any of the species of Devonian Productella known to me, and I therefore place it

in the above named new species. This shell has some similarity with some middle-sized, but very ventricose forms of *Stropheodonta demissa*, from which it is, however, easily distinguished by its smooth surface, which shows only a few spine-bases, while *Stropheodonta demissa* is covered by radiating striae, and never becomes fully as ventricose as our shell. The specimen illustrated is of about average size."

Rare, not seen by the writer.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Centronella glansfagea (Hall).

Pl. XI, figs. 1, 1a, 1b.

C. glansfagea Hall, Pal. N. Y., 1867, Vol. IV, p. 399, Pl. 61A, figs. 1-21, 25, 26.

Hall's description.—"Shell small, broad ovate, or subquadrate; the sides often sloping from near the middle to the apex at an angle of about 85 degrees; the front rounded; the valves very unequal. Ventral valve much larger than the dorsal, very prominent, often subcarinate along the middle and curving very abruptly to the lateral margins, regularly arcuate from beak to base. Beak much extended beyond that of the opposite valve, strongly incurved, bringing the apex above the plane of the margin of the dorsal valve. Dorsal valve usually convex in the upper part, concave in the middle by a broad and undefined sinus, which toward the front often involves the entire width of the valve; beak not incurved. Surface smooth or with faint concentric lines of growth; shell compact and very finely punctate. The shell varies from three-fourths to four-tenths of an inch in length; the width usually more than three-fourths as much, and sometimes nearly equal to the length. The interior of the ventral valve shows two strong teeth, at some distance below the apex with strong dental lamellae. The interior of the dorsal valve shows the bases of the crura to be very thick and strong, entirely dividing at the center and each supporting a thin filament which becomes broader below and sends off a spur into the ventral cavity; and thence curving inwards the outer margins are united and produced along the line of junction in a slender elevated carina, which extends forward in a slender free point. The muscular imprint is oval, and divided along the center. The casts of the interior preserve the impression of the features described, and are readily recognized by the slender incurved filling of the rostral cavity."

The extremely ventricose type shown in some of Hall's figures is not represented in the collections at hand, the sinus being developed the entire length of the dorsal valve. The largest specimen measures five-eighths of an inch in length and one-half inch in width. The shell figured is of the average size.

This is one of the rare species.

Formation and locality.

Sellersburg beds; Charlestown and Falls of the Ohio.

Vitulina pustulosa Hall.

Pl. XI, figs. 2, 2a, 2b.

V. pustulosa Hall, Pal. N. Y., 1867, Vol. IV, p. 410, Pl. 62, fig. 1.

Hall's description.—"Shell subplano-convex, semielliptical; hinge line equaling or a little less than the length of the shell; surface marked by a few strong plications, and covered by minute papillae, which appear like the bases of setae. Substance of the shell finely punctate. Ventral valve very convex; the apex a little acute, subangular in the middle above, and the elevation continued in a broad fold, which is at first flattened and then becomes grooved or duplicate below, with four or five rounded or subangular plications on each side; the area much elevated and the margin rapidly sloping from the apex to the cardinal extremities; foramen large and wide, being half the length of the area, and reaching to the apex; deltidial pieces or pseudodeltidium unknown. Dorsal valve flat or slightly convex with a wide mesial depression which is nearly flat in the bottom, and in larger specimens has a shallow groove in the middle toward the front. The plications on the side correspond with those of the ventral valve. There is a narrow scarcely perceptible area. Surface covered by minute papillae. Substance finely punctate. In the interior of the ventral valve, the margins of the foramen are extended in two strong teeth, which are supported on the lower and lateral margins by a callosity of the shell. Beneath the apex a strong callosity or false area extends across the valve and reaches to the base of the teeth. This callosity is visible in the foramen, and from its lower margin proceeds a slender median septum. On each side of this septum, at its junction with the transverse callosity, there is a small pit for the occlusor muscle; and beyond that a broad flabelliform area for the divaricator muscular attachments. These features are showns in the cast, fig. 1i."

In the dorsal valve there is a strong median ridge or septum which terminates in a slightly lobed cardinal process; on each side of this

are the crural processes, and between these and the margin are the teeth sockets.

This is a rare shell. The collection of Mr. G. K. Green, however, contains 25 or 30 specimens, including single valves.

Formation and locality.

Sellersburg beds; Charlestown.

SPIRIFER.

A. Ventral valve with very high area and beak incurved but slightly or not at all.
- b. Plications angular, not more than twelve or fifteen on each side of fold and sinus.
  - c. Ventral valve with distinct linear ridge along margin of area. *Spirifer arctisegmentum.*
  - cc. Ventral valve without linear ridge along margin of area.
    - d. Shell large with ten or twelve plications each side of fold and sinus. *Spirifer manni.*
    - dd. Shell small with eight or ten plications on each side of fold and sinus.
      - d¹. Sinus rounded in bottom. *Spirifer varicosus.*
      - d². Sinus angular in the bottom. *Sp. hobbsi.*
- bb. Plications rounded or very slightly angular, 16 or more on each side of fold and sinus.
  - e. Shell large, area not inclined forward.
    - f. Surface with 20 to 30 plications which frequently have a thread-like groove in the middle, on each side of the fold and sinus. *Sp. audaculus.*
    - ff. Surface with 16 to 20 plications without a thread-like groove on each side the fold and sinus.
      - g. Area concave. *Sp. macconathii.*
      - gg. Area straight. *S. fornacula.*
  - ee. Shell large, area inclined forward. *Sp. segmenta.*

AA. Ventral valve with low or only moderately high area, beak incurved.
- f. Plications on fold and sinus.
  - g. Plications few, about ten on each side of fold and sinus, smaller in sinus than elsewhere. *Sp. grieri.*
  - gg. Plications numerous, usually about 20 or more on each side of fold and sinus, those in sinus equally developed with the others. *Sp. divaricatus*
- ff. No plications on fold or sinus.
  - h. Hinge line greatly extended.
    - i. Area of ventral valve high and incurved.
      - i¹. Surface marked by fine radiating striae. *Sp. iowensis.*
      - i². Surface not marked by radiating striae. *Sp. macrus.*
    - ii. Area of ventral valve narrow, not incurved. *Sp. pennatus.*
  - hh. Hinge line not greatly extended.
    - j. Shell large.

k. Mesial fold and sinus rounded.
Sp. granulosus.
kk. Mesial fold and sinus sharply angular.
Sp. acuminatus.
jj. Shell small.
l. Plications sharply angular, sinus angular at the bottom. *Sp. byrnei.*
ll. Plications rounded, sinus rounded in the bottom.
m. Mesial fold narrow, area of ventral valve sublinear.
Sp. duodenarius.
mm. Mesial fold wide, area of ventral valve rather high.
n. Surface of shell covered with concentric striae which are strongest toward the front.
o. Shell very gibbous, length usually equal to or greater than width. *Sp. gregarius.*
oo. Shell not very gibbous, length usually much less than width.
Sp. gregarius var. *greeni.*
nn. Surface smooth except near the front where there are from five to seven strong imbricating lines of growth. *Sp. davisi.*

Spirifer divaricatus Hall.

Pl. VIII, figs. 5, 5a.

S. divaricata Hall, Pal. N. Y., 1867, Vol. IV, p. 213, Pl. 32, figs. 1-6.

Hall's description.—"Shell ventricose, somewhat rhomboidal or quadrilateral (looking upon the ventral valve). Dorsal valve semi-elliptical; hinge line less than the width of the shell; cardinal extremities obtuse or rounded; area large. Ventral valve most convex above the middle, extremely arcuate from the umbo to the base, abruptly curving to the sides; beak abruptly arching over the area; sinus plicated, shallow above and becoming rapidly expanded below with the margins undefined and terminating in a broad triangular extension in front. Area high, flat below, abruptly arcuate above and reaching to the cardinal extremities; foramen large. Dorsal valve regularly and strongly convex, with an angular mesial fold,

which is narrow above and expands toward the front with bifurcating plications; sides regularly curving and sometimes a little flattened toward the cardinal extremities. Area rather wide with the beak and central portions of the valve arching over it. The surface is marked by numerous fine bifurcating rounded or subangular plications; the mesial sinus having on either side a stronger plication which bifurcates on one or on both sides. At the beak there is a single plication in the bottom of the sinus, which sometimes continues simple nearly or quite to the base; while the accessions take place mainly from those on the sides of the depression, till they reach the number of ten, eleven or twelve within the limits of the sinus near the base. In a specimen of ordinary size, where the surface is well preserved, there can be seen sixty or more plications with their divisions at the margin of the shell. In some specimens from the Corniferous limestones where the surface is partially or entirely exfoliated the bifurcating character of the striae is not observed; and in one specimen they appear to have been nearly simple throughout. The plications are crossed by fine imbricating lamellose striae which are abruptly arched backwards. A cast of a ventral valve shows a long oval muscular area which is deeply divided by a rounded median crest, and strongly striated on the lateral portions."

In perfectly preserved specimens the transverse striae have a fimbriate character. One shell in Mr. Green's collection has a width of three inches but the shells are usually much smaller than this.

This species appears to be more common in northern than southern Indiana. It is rather common, however, in the bed of limestone frequently found just over the "Cement rock" in southern Indiana.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Pipe Creek Falls, Bunker Hill and Clark County.

Spirifer acuminatus (Conrad).

Pl. IX, fig. 1.

Sp. acuminata Hall, Pal. N. Y., 1867, Vol. IV, pp. 198, 234, Pl. 29, figs. 9-18; Pl. 35, fig. 24.

Hall's description in part.—"Shell large ventricose, transverse, with the hinge line usually less than the width of the shell; cardinal extremities rounded or truncate, having a subelliptical or subquadrate outline; mesial fold and sinus extreme. Surface plicated. Ven-

tral valve variably convex on the two sides, with a wide mesial sinus which is well defined in the upper part, becomes wider and deeper and less distinctly defined in the middle of the shell, and is produced in part in a long triangular extension; gently or more abruptly curving from the greatest convexity to the sides and cardinal angles, with the margin rounded except towards the extremities. Dorsal valve gibbous slightly elevated in the middle into a strong angular mesial fold, and curving from the sides of the fold to the margins of the shell, except at the cardinal angles, where it is a little flattened and projecting, so as to give a minute auriculate appearance; summit of mesial fold regularly arcuate from beak to base; apex slightly incurved over the narrow nearly vertical area. Surface on either side of the mesial fold and sinus marked by from sixteen to twenty plications, about four or five of which nearest the center are dichotomous from below the middle of their length; ribs low and rounded above, flattened below the middle, those near the margin very slender; the first ten or twelve ribs on each side occupy the greater part of the valve. The entire surface is marked by delicate concentric striae, which are often crowded into imbricating lamellose lines towards the front of the shell. In very perfect specimens these concentric striae are papillose or fimbriated by fine radiating striae. These fine surface markings, however, are usually nearly or quite obliterated."

This is one of the most abundant and characteristic fossils of the Indiana Devonian. In southern Indiana, where the Sellersburg beds have their typical development, I have not seen this species above their base, but at North Vernon and other points where there is no very evident lithological distinction between this formation and the Jeffersonville limestone, *Sp. acuminatus* occurs abundantly immediately below the Black shale. In northern Indiana this fossil has not been found in the highest fauna of the Devonian limestone, but occurs in the lower one.

Formation and locality.

Jeffersonville limestone; throughout the Devonian area.

Spirifer gregarius Clapp.

Pl. X, fig. 3.

Sp. gregaria Hall, Pal. N. Y., 1867, Vol. IV, p. 195, Pl. 28, figs. 1-11.

Hall's description.—"Shell ventricose, subglobose, semioval or subquadrate in outline; hinge line equaling or less than the width of

the shell; cardinal extremities truncate or rounded. Surface plicated. Ventral valve the more gibbous, regularly arcuate from beak to front, the greatest convexity at or a little above the middle, and curving somewhat abruptly to the sides and more gently to the front; beak much elevated and the apex closely incurved over the fissure; area high concave and extending to the cardinal angles where it is sometimes more than half a line high, often distinctly striated; mesial sinus rounded or subangular and much produced in front. Dorsal valve very convex, with a strong mesial fold, either angular or somewhat flattened along the summit, and sometimes marked by an indistinct groove; beak often considerably elevated and slightly inclined over the hinge line; area narrow except in the center where it perceptibly widens. Surface marked by from six to ten strong rounded ribs on each side of the mesial fold and sinus;.the entire surface with undulating concentric striae, which towards the front become strong zigzag imbricating lines. The interior of the ventral valve presents a well defined oval muscular impression with a low crest in the centre. The dental plates are often much thickened, filling the entire rostral cavity and encroaching upon the muscular area. The width of the species ranges from one-half to seven-eighths of an inch, and the length is sometimes a little greater but usually a little less than the width. In the more gibbous specimens the beak of the ventral valve is so extremely elevated that one-half the length of the valve is above the cardinal line. In the majority of specimens there are about six or seven plications on each side of the valve. The variable gibbosity gives an apparent variation in the height of the area, the beaks of the two valves sometimes approaching close to each other."

This shell is extremely abundant at the Falls of the Ohio and elsewhere in Clark County, but I have not seen it in northern Indiana.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Falls of the Ohio, Charlestown and Scott County.

Spirifer gregarius var. *greeni* n. var.

Pl. X, figs. 4, 4a.

The collection of Mr. Green contains several specimens which differ considerably from the ordinary type of *Sp. gregarius.* They are very much less gibbous, comparatively wider, the width always exceeding the length, and do not have the strong imbricating striae toward the front which characterize *Sp. gregarius.*

This variety was illustrated by White (Rept. Ind. Geol. Surv. 1880, Pl. 4, figs. 10-11) but no attention was called to the difference between it and the ordinary form.

Formation and locality.
Jeffersonville limestone; Falls of the Ohio.

Spirifer grieri Hall.

Pl. VIII, fig. 6.

Sp. grieri Hall, Pal. N. Y., 1867, Vol. IV, p. 194, Pl. 27, fig. 29; Pl. 28, figs. 17-23.

Hall's description.—"Shell gibbous, transversely oval or subquadrilateral, sometimes longitudinally ovate, the proportions of length and breadth being variable; hinge line usually shorter than the width of the shell, with the cardinal extremities rounded; valves subequally convex. Ventral valve gibbous or ventricose, most convex above the middle and nearly opposite the center of the hinge line and sloping very abruptly to the lateral margins; sometimes regularly arcuate in the entire length and often arched in the upper part and nearly straight below. Umbo prominent and much elevated above the hinge line; beak more or less extremely incurved over the high arcuate area which has a length of from one-half to two-thirds the width of the shell; mesial sinus wide and deep, subangular in the lower part. Dorsal valve regularly arcuate, the greatest convexity near the middle and regularly curving to the lateral margins; mesial fold prominent sometimes rounded but usually more or less distinctly angular; beak small, slightly incurved over a nearly vertical narrow area. Surface marked by six, eight or ten more or less rounded simple plications on each side of the mesial fold and sinus; while there are three or four distinct bifurcating or dichotomous plications upon the fold or sinus, giving six or seven at the margin of the shell. In perfect specimens, the surface is covered by fine concentric lamellose striae which are crossed by delicate radiating striae. This species is distinguished from most of the allied forms by its simple strong plications on each side the mesial fold and sinus, while those occupying the latter are smaller and bifurcating. Sometimes the middle plication on the mesial fold is simple, in which case the fold is quite angular; while in other instances it bifurcates, leaving a longitudinal depressed line in the middle, giving it a more rounded outline. It is only in specimens which have suffered no injury by wearing or exfoliation, that the fimbriate appearance of the concentric markings is visible. In some of the larger or older individuals

the plications are low and gently rounded. In other specimens they are prominent, while from exfoliation they often become angular and more conspicuous; and the same appears to be true of the dichotomous plications of the mesial fold and sinus. In two or three instances I have noticed in the casts a partial bifurcaton of one or two of the lateral plications. In some of the casts or partial casts, the plications on the fold or sinus appear to be partly or entirely obsolete. The interior of the valve is unknown."

This is a rare species.

Formation and locality.

Jeffersonville limestone; Paris Crossing and Falls of the Ohio.

Spirifer davisi Nettleroth.

Pl. IX, figs. 8, 8a.

Sp. davisi Nett., Ky. Foss. Shells, 1889, p. 112, Pl. 12, figs. 1-4.

Nettleroth's original description.—"The shell is semicircular or subquadrate and gibbous. Hinge line equal or longer than the greatest width of the shell. Cardinal extremities acute and mostly somewhat acuminate. Surface strongly plicated. Ventral valve considerably more gibbous than the dorsal valve, regularly arcuate from beak to front; greatest convexity at or a little above middle, and curving gently to the sides and front except at the cardinal angles, which are somewhat flattened; beak much elevated above that of the opposite valve, and arching over the fissure, but scarcely incurved. Cardinal area high and concave, and reaching to the cardinal extremities. Mesial sinus is broad and rounded and reaches quite to the apex. Dorsal valve gibbous, most convex in the middle, flattened or a little concave towards the cardinal extremities. The mesial fold is very prominent, rounded and regularly arcuate; it has a faint impression extending from beak to middle of valve. The beak is small and arched over the linear area. Surface is marked by six to eight rounded or subangular plications on each side of the mesial fold and sinus. The shell is smooth with the exception of the front part which is marked by from five to seven strong concentric imbricating lines of growth, which reach to the cardinal angles and which give to the shell its peculiar beautiful front view. Such imbricated front is only noted in *Sp. gregaria* and *Sp. mucronata*, in both of which it is less regular and less prominent. Interior of shell is unknown.

"The specimens so far found show great similarity in form, also in size; they measure from one inch to one inch and a quarter in

width, by from three-fourths to seven-eighths of an inch in length. This species is related to *Sp. raricosta* and *Sp. gregaria.* From the former it differs in its greater number of plications; its somewhat acuminate cardinal extremities; its longer and more elevated hinge area, and by its peculiar imbricated front. From *Sp. gregaria* it is distinguished by its larger size, by its smooth shell, by its greater width, and by its less prominent umbo, and also by its more marked imbricated front."

This species is rare.

Formation and locality.

Jeffersonville limestone; Lancaster and Falls of the Ohio.

Spirifer granulosus (Con.).

Pl. IX, figs. 2, 2a, 2b.

Sp. oweni Hall, Pal. N. Y., 1867, Vol. IV, p. 197, Pl. 29, figs. 1-8.

Hall's description.—"Shell more or less ventricose in its different stages of growth, somewhat transversely oval, semielliptical or subquadrate; hinge line about equal to the width of shell; cardinal extremities rounded or subangular. Surface plicated.

"Ventral valve scarcely so gibbous as the dorsal valve, its greatest convexity about the middle of its length, and curving regularly to the margins; beak much elevated above that of the opposite valve and arching over the fissure but scarcely incurved; mesial sinus shallow concave, usually well defined and reaching distinctly to the apex. Area high concave elevated and continuing to the hinge extremities; foramen large, reaching to the apex and sometimes partially filled by the thickening of the dental plates. Dorsal valve the more gibbous, the greatest convexity in the middle and curving regularly to the front and lateral margins and usually a little flattened or concave towards the cardinal extremities; mesial fold prominent, rounded, with a longitudinally depressed line along the middle. Area narrow, vertical or in the plane of the longitudinal axis. The surface is marked by from fifteen to seventeen rounded or subangular plications on each side of the mesial fold and sinus; and these are crossed by distinct concentric striae, which become strongly imbricating, or are marked in strong imbricating lines of growth toward the margin. In well preserved specimens there are distinct radiating striae. In many of the silicified specimens, however, both the radiating and concentric striae are partially or entirely obliterated. The interior of the ventral valve shows two short and rather strong teeth, with the ventral portion quite solid. The dental plates reaching to the

bottom of the cavity of the shell, curve slightly outwards and partially enclose an oval muscular area which, in its upper part is divided by a short prominent median crest. In some silicified specimens the conical spires are partially preserved. The crura are widely separated at their bases and converging somewhat abruptly, curve into the dorsal valve, making twelve or more turns, and producing a short, strong spire. In well preserved specimens the mesial fold and sinus are usually sharply defined, but in some of the more gibbous forms the sinus is very broad and one or two of the plications on each side are involved in the sides of the depression; at the same time the mesial fold is very prominent, rounded, and sloping almost imperceptibly into the general contour of the convexity of the valve."

This species frequently has as many as twenty plications on each side of the fold and sinus. The spires are pointed toward the cardinal extremities at an angle of about 45 degrees to each other. In six specimens in Mr. Green's collection, the number of coils in the spire varies from 18 to 21. This is one of the most abundant species in the "Cement rock" of southern Indiana.

Formation and locality.

Sellersburg beds; Sellersburg, Watson, Charlestown, Utica, Falls of the Ohio, Lexington and Paris Crossing.

Spirifer fornacula Hall.

S. euruteines Hall, Pal. N. Y., 1867, Vol. IV, p. 209, Pl. 31, figs. 14-19.

Hall's description.—"Shell semielliptical; length and breadth about as six to ten; hinge line equal to the greatest width of the shell. Surface plicate. Ventral valve subpyramidal, the elevation being equal to nearly half the width, curving abruptly and equally to the front and lateral margins; the distance from the apex to the cardinal extremity and to the front of the shell being about equal. Apex sometimes projecting slightly over the area; mesial sinus shallow, well defined, and reaching to the apex, sometimes a little flattened in the bottom. Area extremely elevated, nearly flat or slightly concave above; fissure large and open to the apex, the length of the sides being about once and a half the width of the base. Dorsal valve moderately and evenly convex with a well defined low rounded mesial fold; beak and margins of the valve in the middle slightly arched. Area narrow at the sides, but having the width of a line in the middle. Surface marked by from sixteen to twenty plications on each side of the mesial fold and sinus; these plications are rounded

and well defined; about eight of them reach the apex on the ventral valve, and the remainder coalesce with the angular border of the area. In perfect specimens the entire surface has been covered by fine concentric undulating striae, which are crossed by fine radiating striae. The remains of these upon some silicified specimens give a granulose surface. The length of full grown individuals is a little more than three-fourths of an inch with a width of about an inch and three-eighths; the height varies from three-fourths of an inch to a little less."

Hall described, under the name of *S. euruteines* var. *fornacula,* a variety of this species from the Bake Oven, Illinois, which is characterized by the incurving of the upper part of the area. This variety is very common in Indiana.

The height of the area varies considerably; in some of the higher forms it is contained in the length of the ventral valve one and two-third times, while in the flat lower types the length of the ventral valve is equal to two and a half times the height of the area. *S. euruteines* is always associated with *Sp. granulosus* in southern Indiana and is nearly as abundant.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Falls of the Ohio, Charlestown, Lexington, Lancaster, Watson, Sellersburg, Kent, Pipe Creek Falls.

Spirifer manni Hall.

Pl. X, figs. 1, 1a.

Sp. manni Hall, Pal. N. Y., 1867, Vol. IV, p. 211, Pl. 31, figs. 20-30.

Hall's description.—"Shell semielliptical or subquadrate; valves very unequally convex; hinge line equal to the greatest width of the shell; cardinal extremities angular, and sometimes produced in acute extensions. Ventral valve subpyramidal, the height often nearly equal to two-thirds the length; greatest elevation at the apex and thence curving to the front and lateral margins; mesial sinus angular above, and rounded or flattened toward the front; margins angular and sharply defined. Area large and high, flat and inclined a little backwards or slightly concave; foramen large and open to the apex. Dorsal valve more or less gibbous and sometimes only moderately convex, curving to the front and lateral margins, and a little flattened at the cardinal extremities; mesial fold moderately elevated, strongly defined and flattened or concave on the summit; the beak

and adjacent portion of the margin is more or less arcuate, and the area is concave for more than half its length on each side of the center. The surface is marked by ten or twelve plications on each side of the mesial fold and sinus; the plications rounded or subangular and sometimes subnodose on exfoliation. Portions of the shell preserved on some of the specimens, show strong lamellose concentric striae, with faint radiating striae."

This shell is very closely related to *Sp. fornacula*. It has a more angular sinus and fewer striae than that species. It is a rare fossil.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Spirifer segmentum Hall.

Pl. IX, figs. 7, 7a.

Sp. segmenta Hall, Pal. N. Y., 1867, Vol. IV, p. 207, Pl. 31, figs. 14-19.

Hall's description.—"Shell transverse semioval; length less than half the width; hinge line equaling the greater width of the shell, and terminating in salient angles. Surface plicate. Ventral valve much elevated, subpyramidal, most prominent at the beak, which is not incurved; sinus strongly defined, shallow and nearly flat in the bottom, with the sides straight, giving a triangular form in which the sides are about once and a half as long as the base. Area very large with sharply angular margins a little inclined forward, and nearly of the same size as the exterior; the fissure is high and large, being nearly of the same dimensions as the mesial sinus. Dorsal valve depressed convex and flattened toward the cardinal extremities, larger than the ventral valve, semielliptical in form with a low but sharply defined mesial fold which is barely flattened upon the summit. The proportions in height of area, length of dorsal and length of ventral valves is about as five, six and seven. Surface marked by twenty or more simple rounded (or subangular) plications on each side of the mesial fold and sinus, the lateral ones of which do not reach the beak, but run out along the margin of the valve. In its perfect condition the shell has been marked by fine concentric striae, traces of which are still preserved, together with stronger imbricating lines of growth."

This is a very common shell in southern Indiana.

In specimens which have been studied from southern Indiana the inclination of the area to the plane passing through the margins of the two valves varies between 60 degrees and 75 degrees. A specimen

from northern Indiana shows an angle of 58 degrees, the lowest noted.

This species is very closely related to *Sp. angustus* if not identical with it; but I have seen no specimens in Indiana with the extremely mucronate hinge extremities shown in Hall's figures of *Sp. angustus*.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Falls of the Ohio, Charlestown, Sellersburg, Kent, Lexington and Pipe Creek Falls.

Spirifer varicosus Hall.

Pl. IX, fig. 3.

Sp. varicosa Hall, Pal. N. Y., 1867, Vol. IV, p. 205, Pl. 31, figs. 1-4.

Hall's description.—"Shell somewhat semicircular or semielliptical; length equaling or less than half the width; hinge line equal to the greatest width of the shell, and terminating in salient angles or mucronate extensions. Surface plicated. Ventral valve much the more convex; greatest elevation at the umbo, and regularly curving to the front and lateral margins; mesial sinus strongly defined, rather flat in the bottom; beak slightly arcuate. Area high, nearly flat below and slightly concave towards the apex. Dorsal valve moderately convex with a prominent abruptly elevated mesial fold, which is flattened on the summit and sometimes slightly depressed along the center; the beak projecting a little above the hinge line, and with a narrow area gently incurved. The surface is marked by from eight to ten simple and somewhat abruptly elevated plications on each side of the mesial fold and sinus; these are crossed by strong lamellose imbricating lines of growth, which give a varicose character to the surface, and where the shell is exfoliated the plications are nodose. In some specimens distinct fine radiating striae can be observed. There is often a retral curving of the striae in the centre of the mesial sinus, and sometimes a slight elevation along that line."

This is a very common little shell.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; throughout the Devonian area.

Spirifer byrnesi Nettleroth.

Pl. IX, figs. 6, 6a.

Sp. byrnesi Nett., Ky. Foss. Shells, 1889, p. 109, Pl. 10, figs. 1-5, 31-34, 36-39.

Nettleroth's original description.—"Shell subquadrate, semicircular and gibbous in outline; hinge line equaling greatest width of shell

and terminating in salient angles. Surface plicate. Ventral valve ventricose and only a little more gibbous than the other valve; regularly arcuate from beak to front; greatest convexity in the upper part a little above the middle from where it curves regularly to the front and sides; beak much elevated above the hinge line and slightly arcuate. Cardinal area high concave and extending to the cardinal angles where it never forms an acute angle, but shows always a height of from one-quarter to one-half a line, a feature which is not sufficiently expressed in the figures on plate 10. Mesial sinus sharply defined, forming a deep triangular groove, with an acute angle at the bottom, much produced in front; fissure of medium size. Dorsal valve gibbous with a greatly elevated mesial fold, which is edged in its upper part and rounded below; beak little elevated and slightly inclined over a narrow hinge area. Surface marked by from eight to ten very prominent and angular plications on each side of the mesial fold and sinus which are crossed by strong imbricating concentric lines of growth, showing more prominently in front than in upper portion of shell. Of the plications the lateral ones do not reach to the beak, but run out on the margins of the cardinal area. The dimensions of this species are as follows: It measures from one-half to three-fourths of an inch in length and from three-fourths to seven-eighths of an inch in width; its width always exceeds its length. This species takes an intermediate position between *Sp. gregaria* and *Sp. varicosa;* it is more transverse than the former and less so than the latter; its umbo is less elevated and curved than that of *gregaria* and more so than that of *varicosa;* its deeper and sharply angular sinus and its more elevated fold, distinguish it from both of its relations. It is a well marked and easily recognized species."

This is a very abundant shell.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; throughout the Devonian area.

Spirifer varicosa var. *hobbsi* (Nettleroth).

Sp. hobbi Nettleroth, Ky. Foss. Shells, 1889, p. 121, Pl. 10, figs. 21, 22, 26-30, 35-40.

An examination of the type specimens of Nettleroth's *Sp. hobbsi* indicates that the only difference between it and *Sp. varicosa* is in the character of the sinus; the sinus in *hobbsi* is rather sharply angular, while in *varicosa* it is usually rounded or flattish. This character is variable in *Sp. varicosa;* sometimes the sinus approaches the

angular type and sometimes a partially developed plication occupies the bottom of it.

This variety is not very common.

Formation and locality.

Sellersburg beds; Falls of the Ohio.

Spirifer arctisegmentum Hall.

Sp. arctisegmenta Hall, Pal. N. Y., 1867, Vol. IV, p. 208, Pl. 31, figs. 9, 10.

Hall's description.—"Shell transversely semioval; length less than one-third the width; hinge line equal to the greatest width of the shell, and terminating in mucronate points. Ventral valve the more convex, most prominent at the umbo from which it slopes regularly to the anterior and lateral margins; mesial sinus angular, and distinctly defined quite to the apex of the shell; beak not incurved. Area flat, a little inclined forwards, striated longitudinally, fissure narrow and open to the apex. Dorsal valve depressed convex, scarcely flattened towards the cardinal extremities; the beak and central portion of the shell, together with the linear area, slightly incurved. The surface of the ventral valve is marked by eight or nine angular plications, which are slightly curved towards the front and about three of them only reaching the apex; the remainder coalesce with an elevated ridge which borders the area. The plications on the dorsal valve are pretty direct, the greater part of them terminating in the margin at a distance from the beak. Fine close concentric striae mark the entire surface."

This is a rare species.

Formation and locality.

Sellersburg beds; Kent and Falls of the Ohio.

Spirifer audaculus (Conrad).

Pl. VIII, fig. 4.

This species is closely allied to *Sp. fornacula.*

Only a few well preserved specimens have been seen; these have the fold and sinus and plications marked by fine closely arranged striae, with a thread-like groove along the middle of each plication.

Formation and locality.

Sellersburg beds; Watson.

Spirifer duodenarius (Hall).

Pl. IX, fig. 10.

Sp. duodenaria Hall, Pal. N. Y., 1867, Vol. IV, p. 189, Pl. 27, figs. 13-16; Pl. 28, figs. 21-33.

Hall's description.—"Shell transverse semicircular; hinge line equaling the greatest width of the shell; cardinal extremities obtuse or acute, rarely acuminate. Valves subequally convex; area very narrow. Surface plicated. Ventral valve moderately gibbous, arcuate, compressed towards the cardinal extremities. Mesial sinus of moderate width and depth, rounded or slightly flattened on the bottom; umbo prominent, the beak small neatly curved over a wide triangular fissure, and reaching to within half a line of the umbo of the opposite valve; area concave, sublinear, a little wider on each side near center. Dorsal valve regularly convex, a little gibbous in the middle, and flattened or sometimes slightly concave at the cardinal extremities. Mesial fold rather narrow, rounded prominent, and strongly defined, sometimes a little flattened on the middle. The surface is marked by six and rarely seven strongly rounded ribs on each side of the mesial fold and sinus. The ribs gradually decrease in size and prominence from the center, and the outer ones are often scarcely elevated in young or medium sized individuals. The entire surface is marked by lamellose concentric striae giving a papillose or subfimbriate aspect at their junction. It usually happens however that the surface is smooth from partial exfoliation. In the Schoharie grit, the cast of the ventral valve shows a somewhat narrow muscular area, with the sides subparallel for half their length and contracting below. There are faint indications of a median crest. In the interior of a ventral valve from the Corniferous limestone, Pl. 28, fig. 23, the muscular area is broad and rounded, with a distinct median crest. A cast of the dorsal valve shows rather shallow teeth sockets, with a strong callosity between them and the fissure, while the apex is marked by muscular impressions."

This species is very rare.

Formation and locality.

Sellersburg beds; Charlestown and Falls of the Ohio.

Spirifer iowensis Owen.

Sp. pennata Hall, Geol. Surv. of Iowa, I, Pt. II, 1858, pp. 5-10, Pl. 5, fig. 1.

Hall's description.—"Shell variable in form from subglobose to transverse and broadly triangular, often inequilateral; hinge line ex-

tremely extended in wing-like expansions; valves often nearly equally convex. Ventral valve very gibbous in the middle and on the umbo; beak much elevated above the hinge line, more or less pointed and slightly incurved; mesial sinus strongly defined at the margins, widely spreading towards the base, and produced in an angular extension in front; area concave and very large, extending to the extremities of the hinge line, striated vertically and longitudinally; foramen large and open to the apex, and forming an equilateral triangle. Dorsal valve very gibbous in the middle and upon the umbo which is abruptly incurved; regularly curved towards the baso-lateral margins, and more or less compressed towards the lateral extremities; mesial fold strongly elevated, sometimes a little flattened on the top, and often subangular towards the front and slightly depressed on each side. Surface marked by fourteen to twenty-six or more rounded plications on each side of the mesial fold and sinus; those near the center to the number of ten or twelve being much stronger than those upon the extremities, which become finally very slender. Plications crossed by closely arranged concentric undulating lamellae of growth; and the entire surface in perfect specimens ornamented by slender radiating striae which become granulose at their junction with the concentric striae."

I have not seen any perfect specimens of this shell.

Formation and locality.

Sellersburg beds; Paris Crossing, Watson, Falls of the Ohio.

Spirifer macconathei Nettleroth.

Sp. macconathei Nett., Ky. Foss. Shells, 1889, p. 123, Pl. 11, figs. 1-5.

Nettleroth's description.—"Shell transverse, triangular or semielliptical; hinge line much extended, extremities often mucronate; valves unequal in depth; area large surface plicate. Ventral valve elevated at the beak; abruptly sloping to the front and lateral margins, but with little convexity. Area one-third as high as long, and only slightly concave; fissure about twice as high as wide, and reaching to apex of valve; beak minute. Mesial sinus well defined but shallow and flattened at the bottom, with subangular margins rapidly widening toward the front, where it is somewhat produced. Dorsal valve depressed convex, most convex in the middle; cardinal extremities often inflected; beak not prominent, incurving over the linear area. Mesial fold well defined and rounded, but flattened on top toward the front. Surface marked by from eighteen to twenty simple

rounded plications on each side of the mesial fold and sinus; only a few of these ribs reach to the beak, the others run out on the margins of the cardinal area. This species agrees in many points with Prof. Hall's description of *Sp. macronata,* in Pal. N. Y., Vol. IV, p. 231, but it differs by its smaller number of ribs which in this species never exceed twenty while *macronata* has from twenty-five to thirty-five. The area of *macronata* is straight while that of *macconathei* is always concave, and the surface of the last species is generally smooth, while the surface of the former is covered by several lamellose imbricating lines of growth."

I have not seen this species. Nettleroth reports it to be rare.

Formation and locality.

Sellersburg beds; Falls of the Ohio.

Spirifer pennatus (Atwater).

Pl. VIII, figs. 1, 2, 2a.

Sp. mucronata Hall, Pal. N. Y., Vol. IV, 1867, p. 216, Pl. 34, figs. 1-32.

Hall's description in part.—"Shell more or less gibbous, semicircular, semioval or triangular in outline; cardinal angles sometimes truncate but usually extended and often extremely prolonged into mucronate points, giving a length of hinge line two, three or four times as great as the shell; sides straight or curving, the front straight or concave. Ventral valve often scarcely more convex than the dorsal, but in very gibbous forms becoming more unequal, gently curving to the lateral margins. The beak is small and incurved over the narrow linear area; the mesial sinus is sharply defined quite to the apex, and limited by angular plications which are stronger than the adjacent ones. The prevailing form of the sinus is shallow and rounded in the bottom; it is sometimes flat and sometimes with a fold in the center. Dorsal valve moderately convex, sometimes becoming gibbous. The sides are gently curving, and usually flattened towards the cardinal margin; the mesial fold usually prominent and well defined, flat or rounded above, sometimes with a median groove and again angulated in the middle. The beak is incurved and the area extremely narrow, about one-third as high as that of the ventral valve. Surface marked by from eight or ten to twenty or more subangular plications on either side of the mesial fold and sinus; the plications are not very prominent but usually well defined, flat or rounded above, sometimes with a median groove and again angulated in the middle. The beak is incurved and the area extremely narrow,

about one-third as high as that of the ventral valve. Surface marked by from eight or ten to twenty or more subangular plications on either side of the mesial fold and sinus; the plications are not very prominent but usually well defined, the outer half of the number not reaching the beak, but terminating in the callosity along the area margin. The plications are crossed by numerous fine lamellose striae which become crowded together and closely imbricating towards the front of the shell and sometimes presenting several interrupted lines of growth."

This fossil is one of the most abundant species in the upper Devonian limestone fauna in northern Indiana. The specimens do not differ in any respect from the New York specimens. This species is unknown in southern Indiana.

The appearance of the specimens of this fossil in the State Museum credited to Charlestown would indicate that they came from some locality outside the State. They have a very different appearance from that of fossils coming from that locality. No collector so far as I am aware claims to have found this species in southern Indiana.

Formation and locality.

Sellersburg beds; Norway, Delphi, and Little Rock Creek, Cass County.

Spirifer macrus Hall.

Pl. VIII, figs. 3, 3a, 3b, 3c.

Sp. Macra Hall, Pal. N. Y., 1867, Vol. IV, p. 190, Pl. 27, figs. 17-28.

Shell transversely elongate, the hinge line extending somewhat beyond sides of shell and the cardinal angles usually extended in mucronate points; valves about equally convex. Ventral valve regularly convex except near the cardinal extremities where it is somewhat flattened. Beak small and slightly incurved over the large triangular fissure. Area rather high and slightly concave. The sinus is broad and well defined, usually rather deep and angular or subangular in the bottom; in some specimens it is comparatively shallow and somewhat rounded in the bottom. Dorsal valve moderately convex or somewhat gibbous in the middle, becoming flattened or concave toward the cardinal extremities. Mesial fold well developed, rounded or flattened on the summit. One specimen shows a slightly depressed line along the middle of the flattened fold. Area linear, beak very small. Surface marked by from ten to 16 slender angular plications on each side of the fold and sinus. Strong concentric lamellose striae cover the entire surface.

The interior of the ventral valve shows short strong dental plates partially enclosing a deep rather narrow muscular area; in the middle of this area are two long narrow occlusor impressions separated by a low and narrow median ridge.

The interior of the dorsal valve shows two teeth projecting into the cavity of the shell nearly at right angles to each other, and separated from the cardinal area by a shallow groove on the outside of each; the outer surface of each tooth is also marked by a shallow groove. A low linear ridge extends along the middle of the shell half way to the front.

The specimens figured are from Mr. G. K. Green's collection. This seems to be a rare species.

Formation and locality.

Sellersburg beds; Charlestown.

RETICULARIA.

A. Shell subcircular, surface without tubercles.
- **b. Mesial sinus with two plications.** *R. knappiana.*
- **bb. Mesial sinus without plications.** *R. wabashensis.*

AA. Shell transversely subelliptical, surface curved, with tubercles. *R. fimbriata.*

Reticularia fimbriata (Conrad).

Pl. VII, fig. 11.

Spirifer fimbriata Hall, Pal. N. Y., Vol. IV, 1867, p. 214, Pl. 33, figs. 1-11.

Hall's description.—"Shell transversely subelliptical, gibbous; hinge line less than the width of the shell; cardinal extremities rounded. Ventral valve gibbous in the upper half, regularly curving to the front and sides; sinus well-defined, usually shallow and rounded, sometimes deep and angular, and much produced in front; beak small and incurved over the area, which is high and concave, extending about half the entire width of the shell; foramen often limited by a sharp elevated border which appears to be a projection of the dental plates. Dorsal valve gibbous regularly convex on the sides, a little flattened at the cardinal extremities; mesial fold abruptly elevated in the lower part, often but little elevated or scarcely defined in the upper part; beak small, slightly arched over the sublinear area, which is somewhat concave. Surface marked by from three or four to eight or nine plications on each side; these are crossed by imbricating lamellose striae, which are sometimes wide or distant, and often crowded. The concentric striae are studded

with elongated nodes or tubercles, which are thus arranged in parallel bands more or less contiguous, according to the distance of the concentric striae. The elongate tubercles may perhaps more properly be regarded as interrupted radiating striae, which in the perfect condition of the shell have doubtless extended in slender spines or setae. (They are termed by Mr. Conrad longitudinal striae.) The area is strongly striated vertically."

The interior of the ventral valve shows a well marked subovate muscular area with thin dental plates at the sides and a low median septum extending the length of the muscular area. The interior of the dorsal valve shows well developed teeth sockets projecting obliquely into the cavity of the valve.

This is a rather common species in northern Indiana, less common in southern Indiana.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Bunker Hill, Little Rock Creek and Charlestown.

Reticularia knappianum Nettleroth.

Spirifer knappianum Nett., Ky. Foss. Shells, 1889, p. 122, Pl. 7, fig. 14.

Nettleroth's original description.—"Shell subcircular, gibbous; hinge line shorter than the width of the shell; cardinal extremities rounded. Ventral valve gibbous in the upper part, and regularly curving to the front and sides. Mesial sinus well defined from front to apex of beak, somewhat shallow and rounded; it contains two faintly marked plications. Beak of medium size and curved over the area, which is high and concave, extending over about two-thirds of the entire width of the shell; fissure of medium size. Dorsal valve gibbous regularly convex on the sides, a little flattened at the cardinal extremity; mesial fold prominent and well defined to apex of beak, containing on its middle a well marked depression. Beak small, slightly arched over the sublinear area, which is somewhat concave. Surface marked by from six to eight rounded plications on each side of the fold or sinus; they are crossed by imbricating lines or striae which have irregular distances in the upper part but become regular and close set in the front part. The whole surface is covered with very fine closely set radiating striae, but there are no elongated nodes or tubercles as in *conradana*.

"The cardinal area is densely covered with fine closely set radiating striae."

I have not seen this shell. Nettleroth reports it to be rare.

Formation and locality.

"Corniferous"; Falls of the Ohio.

Reticularia wabashensis n. sp.

Pl. X, figs. 5, 5a, 5b.

Shell subcircular in outline, hinge line less than width of shell; cardinal extremities rounded. Ventral valve slightly more convex than dorsal, most gibbous at the umbo from which it slopes regularly to the front and sides; beak elevated and incurved over a rather high short area which scarcely reaches to the extremities of the hinge line; sinus broad and shallow reaching to the apex of the beak, somewhat extended in front. Dorsal valve regularly convex; mesial fold prominent, rounded or rarely with a depressed line in the middle; beak small, slightly arched over the sublinear area.

Surface marked by from three to five low rounded plications on each side the fold and sinus. Entire surface covered by fine radiating striae. A few specimens have traces of concentric striae.

This shell differs from *R. fimbriata* in the absence of surface tubercles, and in the comparatively shorter transverse diameter.

Common in northern Indiana.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls and Bunker Hill.

Gypidula romingeri var. *indianensis* nov. var.

Pl. VI, figs. 12, 12a.

Shell gibbous, inequivalve, width greater than the length. Ventral valve very gibbous, arching very regularly to the front and sides; a distinct mesial fold towards the front is marked by four strong plications. Dorsal valve convex near the umbo, and becoming nearly flat near the sides of the shell. A well developed sinus marks the anterior half of the valve which is marked by four plications of unequal strength extending rather more than half the length of the valve.

Surface marked by two or three obscure plications on each side of the fold and sinus near the front which become obsolete before reaching the middle of the shell.

Mr. John M. Clarke who kindly compared this shell with the types of *G. romingeri*, observes that it "resembles in many respects the

Gypidula romingeri, especially in the general character of its exterior, its form, proportions, etc., although it is much smaller in size than the prevailing shell in the Hamilton group of Michigan. There is also a marked difference in the degree of surface plication. This is generally much more pronounced in the Michigan form than in your specimen and extends from shoulder to shoulder of the shell."

While the surface plication of this variety is less pronounced than in *G. romingeri* it appears to be much more strongly developed than *G. comis* and in this respect at least it seems to be intermediate between these two types.

Only one specimen is known, which was found by the author and now belongs to the U. S. Geol. Survey.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

MERISTELLA.

A.	**Beak of ventral valve closely incurved.**	***M. nasuta.***
AA.	**Beak of ventral valve not closely incurved.**	***M. barrisi.***

Meristella nasuta (Conrad).

Pl. XII, fig. 7.

M. nasuta Hall, Pal. N. Y., 1867, Vol. IV, p. 299, Pl. 48, figs. 1-25.

Hall's description in part.—"Shell suboval, ovate or subrhomboidal, the greatest width near or a little below the middle; length equaling or greater than the width. Valves convex, the ventral valve gibbous. A nasute or linguiform extension of the front in old shells. Ventral valve much the more convex, the greatest convexity being above the middle, becoming gibbous or extremely arcuate in old individuals, curving abruptly to the sides and cardinal margins, and more gradually to the front; umbo extremely prominent; beak neatly rounded and closely incurved, standing at a right angle with the plane of the axis, or in old shells directed forwards. The anterior portion is produced into a nasute or linguiform extension, usually without a sinus or any depression of the surface. In the young or half-grown individuals this feature does not appear. Dorsal valve less convex than the opposite, moderately and regularly convex in the young shell, becoming in the old shells gibbous above, curving regularly to the sides and often a little flattened at the baso-lateral margins; at about the middle of the length or sometimes above, the central portion of the valve becomes more gibbous and towards the front is abruptly elevated into a short rounded prominent fold, corresponding

to the linguiform extension of the opposite valve. The beak is moderately incurved, lying close beneath that of the opposite valve. The general aspect of the surface is that of a smooth shell with a few concentric lamellose lines. In perfect specimens, however, the entire surface is marked by close concentric striae, and usually by indistinct radiating striae, which are often more conspicuous in the partially exfoliated shell, and still more distinct in some of the casts."

This shell reaches a large size; one specimen in Mr. Green's collection measures one and a half inches in width. A well developed sinus is present in some shells but it is usually represented only by the extension at the front; one specimen shows a low fold in place of a sinus on the ventral valve.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Meristella barrisi Hall.

Pl. XII, fig. 6.

M. barrisi Hall, Pal. N. Y., Vol. IV, 1867, p. 304, Pl. 49, figs. 5-22.

Hall's description.—"Shell ovoid, more or less elongate and sometimes broadly ovate, gibbous; valves subequally convex, sinuate in front. Ventral valve gibbous in the middle, the greatest convexity a little above the middle of its length, and abruptly sloping to its sides, flattened below the middle, becoming depressed towards the front, which in old shells is produced into a short linguiform extension; umbo gibbous, the beak arching over the umbo of the opposite valve and not closely appressed. Dorsal valve little longer than wide, varying from moderately convex to gibbous, the greatest convexity being about the middle of its length; without distinct mesial fold, but abruptly elevated near the anterior margin, corresponding to the depression on the opposite side. Surface smooth or marked by regular concentric striae, which are sometimes crowded into wrinkles near the margin of the valves. The exfoliated shells sometimes show indistinct radiating striae. The muscular impression in the ventral valve is triangular and usually not deeply marked. The dorsal valve has a distinct median spetum which extends nearly half the length of the valve, muscular area narrow elongate. This species presents considerable variety of form, from almost symmetrically oval to broadly ovate, with the greatest width below. The older shells are for the most part gibbous but some specimens are compressed in the lower half of the length. The mesial sinus is not

usually a very distinctive feature in half-grown shells; but in some individuals it begins about the upper third of the shell and affects the lower half and anterior part of the valve. The largest individuals have a length of about one inch and a quarter, with a width of one inch; in other specimens a length of one inch and an eighth gives a width of one inch and a depth of three-fourths of an inch. In a gibbous and somewhat elongate form the depth and width are as 5 to 6 and the length 8½."

Mr. Green's collection contains four specimens which seem to belong to this species, the only ones which I have seen.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

EUNELLA.

A. Shell sinuate or emarginate in front. *E. sullivanti.*

AA. Shell not sinuate or emarginate in front.

- b. Beak of ventral valve extended, not closely incurved. *E. harmonia.*
- bb. Beak of ventral valve rather abruptly incurved. *E. lincklaeni.*

Eunella sullivanti Hall.

Pl. XII, fig. 1.

Terebratula sullivani Hall, Pal. N. Y., 1867, Vol. IV, p. 387, Pl. 60, figs. 5-10.

Hall's description.—"Shell elongate-ovate or subspatulate, truncate or emarginate in front, of moderate convexity; width and length about as four to six or seven to nine. Ventral valve a little less convex than the opposite; the beak much extended, neatly attenuate and perforate at the apex; the cardinal slopes rounded and a little concave near the hinge margin, usually depressed towards the front and sometimes a shallow sinus which reaches one-third or one-half the length of the valve. Dorsal valve a little more convex and considerably shorter than the ventral valve, usually flattened and sometimes depressed along the center of the lower part of the valve. Surface marked by fine close concentric striae which are neatly rounded on well preserved specimens and at intervals are crowded into more prominent ridges. Shell structure punctate. On cutting down a specimen of this species it has been found to possess a short simple loop, without appendage as in *Terebratula.* The larger specimens are about three-fourths of an inch in length."

This is a common species in northern Indiana, but has not been found in southern Indiana. The shells are seldom more than half

an inch in length. They seem to be less convex than the specimens figured by Hall. The greatly extended, nearly straight and attenuate beak is a constant feature but the outline of the shell is extremely variable. Some specimens are deeply emarginate at the front while others are rounded or truncate. The emarginate shells have a sinus in both valves; in the others it is wanting or but slightly developed.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls, Bunker Hill and Little Rock Creek, Cass County.

Eunella harmonia Hall.

Pl. XII, fig. 2.

Terebratula harmonia Hall, Pal. N. Y., 1867, Vol. IV, p. 388, Pl. 60, figs. 11-16.

Hall's description.—"Shell ovate or subspatulate, tapering somewhat abruptly to the beak, convex in the middle and compressed at the margins. Ventral valve regularly ovate from beak to front, moderately convex in the middle, a little gibbous above and depressed-convex or slightly concave towards the front, the upper part narrowing; the beak much extended, attenuate and arcuate, but not closely incurved; apex perforate, the slope to the cardinal margin scarcely concave; deltidial plates large. Dorsal valve moderately convex, sometimes a little more prominent along the middle in the upper part and depressed towards the front and sides. Surface marked by fine concentric lines of growth; the substance of the shell finely punctate. A well marked specimen of this species has been cut down on the dorsal side, revealing the loop, the divisions of which extend for more than one-third the length of the dorsal valve; the angle of return being visible, but not the connecting portion. Young specimens which I refer to this species are more gibbous than the older ones. The larger specimens are from six-eighths to seven-eighths of an inch wide."

This species is rather common in northern Indiana.

Formation and locality.

Jeffersonville limestone; Bunker Hill, Pipe Creek Falls and Falls of the Ohio.

Eunella lincklæni Hall.

Pl. XII, figs. 3, 3a.

Cryptonella lincklaeni Hall, Pal. N. Y., 1867, Vol. IV, p. 397, Pl. 60, figs. 49-65.

Hall's description.—"Shell ovate or subelliptical, usually broader below the middle, varying from moderately convex to very gibbous and sometimes subcylindrical; front rounded subtruncate or a little depressed. Ventral valve varying from moderately convex to gibbous, somewhat regularly arcuate in longitudinal outline, sometimes a little flattened towards the front or marked by a narrow mesial depression. Beak more or less abruptly incurved and truncate by a foramen of moderate size; umbonal slope rounded or subangular, and concave towards the cardinal margin. Dorsal valve varying from moderately convex to gibbous; the greatest convexity about the middle of the length, and thence curving regularly to the sides and base. Surface marked by fine concentric striae of growth, which are sometimes crowded together towards the front, causing a thickening of the shell. Shell structure distinctly punctate. This species presents some variety of form from subelliptical to broad ovate. The length of a large individual is a little more than three-fourths of an inch, with a width of five-eighths of an inch and a depth of three-eighths; while another form which I refer to the same has a length and width of half an inch with a depth of a little more than a quarter of an inch. Some of the smaller individuals are a little more than a quarter of an inch in length."

This is a very common species.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls, Bunker Hill and Falls of the Ohio.

CRYPTONELLA.

A. Shell very gibbous, length of dorsal valve greater than the width. *C. ovalis.*
AA. Shell moderately gibbous, length and breadth of dorsal valve about equal. *C. lens.*

Cryptonella lens Hall.

Pl. XI, fig. 9.

Terebratula lens Hall, Pal. N. Y., 1867, Vol. IV, p. 386, Pl. 60, figs. 1-4.

Hall's description.—"Shell ovate broadly elliptical or lenticular below the beak, which is abruptly tapering; moderately gibbous, the valves subequally convex, the greatest width a little below the mid-

dle, the width about four-fifths as great as the length, and the depth nearly equal to half the length. Ventral valve a little less convex than the dorsal, the beak moderately incurved and broadly truncated by the foramen; no visible sinus or elevation in the middle of the valve. Dorsal valve broadly elliptical or subcircular, somewhat regularly convex; the beak closely appressed below that of the opposite valve. Surface marked by concentric lines of growth; the shell structure distinctly punctate. The length of an ordinary specimen is seven-tenths of an inch, the width six-tenths of an inch."

This is a rather common fossil in northern Indiana but rare in southern Indiana.

Formation and locality.

Jeffersonville limestone; Bunker Hill, Pipe Creek Falls and Falls of the Ohio.

Cryptonella ovalis Miller.

Pl. XI, figs. 8, 8a.

C. ovalis Mill., advance sheets 17th Rep. Geol. Surv. Ind., 1891, p. 76, Pl. 13, figs. 1-2.

Miller's original description.—"Shell subovate, gibbous rounded in front, greatest width slightly above the middle. Surface concentrically banded, the bands apparently imbricating. Shell structure punctate. Ventral valve more gibbous than the dorsal; arcuate from the beak to the front; greatest convexity above the middle. Beak prominent incurved inflected along the umbonal slopes, truncated by a small foramen, no hinge area. Dorsal valve shorter than the ventral, less gibbous, greatest convexity above the middle. Beak incurved beneath the beak of the ventral valve. No hinge area. This species resembles *Cryptonella planirostra,* but is much more gibbous, and the ventral valve is much more convex than the dorsal, while in that species the dorsal valve is most convex. Our specimens vary greatly in length from three to seven-tenths of an inch."

This species closely resembles those specimens of *Cranaena romingeri* which are not sinuate in front and may prove to be a variety of that species. It is not very common.

Formation and locality.

Jeffersonville limestone; Bunker Hill and Falls of the Ohio.

Terebratula jucunda Hall.

Pl. XI, figs 10, 10a.

T. jucunda Hall, Pal. N. Y., 1867, Vol. IV, p. 390, Pl. 60, figs. 29-31.

Hall's description.—"Shell subcircular or very broadly ovate, the length and width about equal, regularly rounded below and abruptly narrowing above the middle. Ventral valve gibbous in the middle, curving abruptly to the base and baso-lateral margins; beak obtuse, and incurved over the umbo of the opposite valve; apex truncated by a rounded foramen. Dorsal valve rather regularly convex, the greatest convexity a little above the middle, curving to the base and baso-lateral margins. Length of specimens a little more than three-eighths of an inch. On cutting down the dorsal side, the loop is visible, showing the terebratuloid character."

This species resembles closely in external features some of the shorter forms of *Cryptonella lens,* from which it is difficult to distinguish it. The outline of the shells referred to this species is more nearly circular than Hall's figure, resembling in this respect *Terebratula ontario.* It is not very abundant.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls, Bunker Hill and Falls of the Ohio.

Cranaena romingeri Hall.

Pl. XII, fig. 4, 4a.

Terebratula romingeri Hall, Pal. N. Y., 1867, Vol. IV, p. 389, Pl. 60, figs. 17-25, 66, 67.

Hall's description.—"Shell ovate, more or less gibbous, truncate or slightly sinuate in front. Ventral valve gibbous above the middle; umbo gibbous, inflated; beak prominent, incurved over the opposite beak, and truncated by a round foramen which is often mainly anterior to the apex and completed on the lower-side by two deltidial plates; cardinal slopes rounded, often depressed in the middle toward the front. Dorsal valve extremely gibbous, little longer than wide, the greatest convexity at the middle or above. Surface marked by fine concentric striae which are often crowded into prominent wrinkles toward the front. Shell structure finely punctate. The interior shows a short terebratuliform loop, which is abruptly recurved at its lower extremities."

The sinus in the ventral valve is more distinctly developed in the specimen figured than in any other specimen which has been ob-

served. In some of the shells referred to this species it is entirely wanting. This is a rather rare species.

Formation and locality.

Jeffersonville limestone; Bunker Hill, Pipe Creek Falls and Falls of the Ohio.

Camarospira eucharis Hall.

Pl. XII, fig. 5.

Camarophoria eucharis Hall, Pal. N. Y., 1867, Vol. IV, p. 368, Pl. 57, figs. 40-45.

Hall's original description.—"Shell broadly ovate, length a little greater than the width. Ventral valve ovate with the beak extended and arcuate, gibbous above the middle, curving gently to the sides, broadly flattened or a little depressed toward the front and terminating upwards in a broad short linguiform extension, giving the anterior margin an abruptly rounded or truncate aspect. Dorsal valve gibbous in the upper part, more abruptly elevated along the middle and towards the front, slightly concave on each side of the broad undefined elevation; anterior margin sinuate. Beak closely incurved into the cavity beneath the apex of the ventral valve. Surface marked by fine concentric striae which at intervals are crowded into lamelliform ridges. Shell apparently impunctate."

Two of my specimens show traces of fine radiating striae near the margin of the shell. This species is not very common.

Formation and locality.

Jeffersonville limestone; Bunker Hill, Pipe Creek Falls, Charlestown and Falls of the Ohio.

PELECYPODA.

AVICULOPECTEN.

A. Ears not well defined. *A. (Pterinopecten?) terminalis.*

AA. Ears well defined.

- b. Radiating striae fasciculate. *A. fasciculatus.*
- bb. Radiating striae not fasciculate.
  - c. Test marked by coarse angular ribs, which are crossed by strong distant lamellose concentric ridges. *A. crassicostata.*
  - cc. Test marked by moderately strong radiating striae which are crossed by fine concentric striae.
    - d. Test marked by strong sharp rays, anterior ear small, posterior ear marked by rays. *A. exacutus.*
    - dd. Test marked by rather fine radiating striae, anterior ear large, posterior ear usually without rays. *A. princeps.*

Aviculopecten princeps (Conrad) Hall.

Pl. XII, fig. 10.

A. princeps Hall, Pal. N. Y., Vol. V, Pt. I, 1884, p. 1, Pl. 1, figs. 10, 11; Pl. 5, figs. 18, 19, 23, 24; Pl. 6, figs. 1-9; Pl. 24, fig. 7; Pl. 81, figs. 13-17.

Hall's description in part.—"Shell large, obliquely broad, ovate; axis inclined more than 60 degrees to the hinge line; length and height nearly equal, varying within moderate limits; anterior margin convex; the convexity increasing to the middle of the posterio-lateral side, thence truncated and extending in a straight line to the beak, making an angle of from 30 degrees to 40 degrees with the hinge line. Valves depressed; left valve regularly convex; right valve nearly flat or very moderately convex. Hinge line straight, having a length of from two-thirds to more than three-fourths the length of the shell, and extending anteriorly as far as the antero-lateral margin with little variation. Beaks obtuse, rounded anterior to the middle of the hinge. Umbo subtending an angle of about 130 degrees. Ears large, triangular; posterior one the larger and defined by the abrupt slope of the side of the umbo, while the anterior ear is separated by a distinct sulcus; lateral margins concave, becoming convex at the hinge line. Byssal sinus broad, rounded, well defined and indicated on the ear by a sulcus extending to the extremity of the beak. The right valve is flatter and proportionally broader than the left. The limits of the ears are clearly indicated by the rapid slope of the umbo, and the absence of strong radiating lines of ornamentation. Test thin, marked by numerous regular alternating rays, which increase in number by interstitial additions, and become broader and stronger toward the margins. These radiating ribs are crossed by very fine sharp striae of growth. On the ears the rays are nearly obsolete, and the lines of growth are sharper and stronger than on the body of the shell."

This is not a common species. *A. pecteniformis* and *A. parilis* have been recognized by Hall as synonyms of *Aviculopecten princeps.*

Formation and locality.

Jeffersonville limestone; Keesport, Cass County and Falls of the Ohio.

Aviculopecten exacutus Hall.

Pl. XII, fig. 11.

A. exacutus Hall, Pal. N. Y., Vol. 5, Pt. I, 1884, p. 8, Pl. 3, figs. 18-22.

Hall's description.—"Shell of medium size, obliquely broad ovate; greatest longitudinal diameter below the middle; height nearly equal

to the length, transverse axis oblique to the hinge line; basal margin full and regularly rounded; posterior margin extended beyond the ear and more convex than the anterior. Valves equally convex; the byssal sinus larger in the right valve and the umbo less ample. Hinge line straight; length four-fifths of the longitudinal diameter, extending nearly as far as the anterior margin. Beaks obtuse, oblique, anterior to the middle of the hinge and of the valve; umbo ample. In some specimens of the left valve the beak arches over the hinge line, while in the right valve the beak rises from the hinge. Ears triangular; posterior one somewhat the larger, margin concave, extremely acute; defined from the umbo by a broad, shallow sulcus, an obscure carination, and an abrupt change in the surface characters to subdued striae. The anterior ear is well defined by the sulcus extending from the angular byssal sinus. Test ornamented by about forty strong, sharp continuous rays, alternating in size with broader and concave interspaces crossed by fine sharp crenulating concentric striae. The ears show finer concentric striae and a few rays. Pallial line impressed continuous, extending parallel to the margin of the shell about half way from the beak, terminating near the center of the posterior side, in a subcircular muscular impression, marked with regular concentric striae. The cast preserves traces of the exterior markings, but presents no definite characters of the hinge. The largest specimen has a height of 35mm. A medium sized specimen has a height of 26mm; length 27mm; hinge line 24mm."

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls.

Aviculopecten fasciculatus Hall.

A. fasciculatus Hall, Pal. N. Y., Vol. V, Pt. I, 1884, p. 11, Pl. 5, figs. 7-19; Pl. 81, figs. 1-4.

A. fasciculatus Nettleroth, Ky. Foss. Shells, 1889, p. 224, Pl. 3, fig. 4.

I have not seen this species. Nettleroth reports it to occur in the "Corniferous limestone" around the Falls of the Ohio.

Aviculopecten (Pterinopecten?) terminalis Hall.

Pl. XII, figs. 12, 13; XIII, fig. 1.

A. (Pterinopecten?) terminalis Hall, Pal. N. Y., Vol. V, Pt. I, 1884, p. 32, Pl. 1, fig. 3.

Hall's description.—"Shell small, rhomboidal body of the shell obliquely ovate; length a little greater than the height, margins

regularly rounded, somewhat extended behind. Left valve very convex. Right valve unknown. Hinge line straight central, equal to the length of the shell. Beak acute, prominent, directed a little forward, arching over the hinge line. Umbo elevated, subtending a right angle. Ears triangular; margins concave; extremities acute. Posterior ear larger undefined. Anterior ear limited by a shallow sulcus. Byssal sinus moderate. Test thin marked by fine sharp radii, with wider interspaces, which show one, two or three finer rays, crossed by fine crenulating lines of growth. The same characters of marking extend over the ears. Internal characters not known. The specimen is 14mm in length, 12mm in height, with hinge line 15mm."

The specimens which I have referred to this species are considerably smaller than the specimen described by Hall, but in other respects there appears to be no important differences.

Formation and locality.

Jeffersonville limestone; Bunker Hill and Pipe Creek Falls.

Aviculopecten crassicostata H. and W.

A. crassicostata Hall and Whitfield, 24th Rept. N. Y. State Mus. Nat. Hist., p. 188.

Hall and Whitfield's original description.—"Shell below medium size, left valve depressed, convex; body of shell oblique, hinge line straight, equal to three-fourths the length of the shell; anterior wing very small, separated from the body of the shell by an abrupt deep sinus; posterior wing narrow, obtusely pointed and extending nearly as far as the posterior extremity. Surface marked by strong coarse angular ribs, of which there are about thirteen or fourteen on the body of the shell, with intermediate smaller ones; about five obscure rays on the posterior wing; the radiating costae crossed by coarse distant lamellose concentric ridges."

This species was described from specimens obtained in "limestone of the age of the Upper Helderburg group" at the Falls of the Ohio. I have not seen it. Nettleroth reports it from the "Hydraulic limestone" (Sellersburg beds).

Limoptera cancellata Hall.

Pl. XIII, fig. 6.

L. cancellata Hall, Pal. N. Y., Vol. V, Pt. I, p. 244, Pl. 26, figs. 1-4; Pl. 92, figs. 1-3.

Hall's description.—"Shell large; body suberect, broadly ovate; axis nearly vertical to the hinge line; wing expanded; height and

length nearly equal; ventral margin very broadly rounded; anterior margin expanded below and contracted above; postbasal side expanded, recurved somewhat abruptly and extending in a subarcuate line to the beak. Valves very unequal. Left valve moderately convex below, gradually becoming gibbous and arcuate above. Right valve concave below, flat in the middle and depressed convex in the umbonal region. Hinge line straight, less than the length of the valve. Beak of left valve prominent, anterior to the middle of the valve, acute, inclined forward and arching over the hinge line. Umbonal region prominent gibbous; abruptly limited on either side. In the right valve the beak does not rise above the cardinal line. Umbonal region defined on the anterior side by a distinct oblique fold or ridge, and on the posterior side by a well-marked depression limiting the wing, subtending an acute angle. Ear small, limited by a shallow sinus below. Wing large, triangular, extending more than half the height of the shell toward the base; margin gently concave and slightly recurving toward the hinge line; extremity angular. Test of moderate thickness, marked by somewhat distant rounded, abruptly elevated radii, with wider intermediate flat spaces, which are sometimes marked by one or more smaller rays. In the partial cast these rays are crossed and the intermediate spaces cancellated by fine concentric striae. Toward the ventral and basolateral margins the shell is lamellose and the radii become obsolete. The concentric striae are crowded upon the wing and the radii are less conspicuous than on the body of the shell. Ligamental area in left valve large; smaller in the right valve. The pallial line in the left valve forms a distinct nodose ridge which extends from the rostral cavity in a slightly arcuate line to below the middle of the valve. In the right valve the pallial line in the cast extends along the ridge, limiting the body of the shell from the anterior alation. In the cast of the left valve the umbonal cavity is marked by numerous nodes indicating pits in the shell for muscular attachment. The posterior muscular impression is large, occupying the post-umbonal slope at a point half-way from the beak to the base of the shell.

"A cast of the interior has a length of about 78mm, height of 77mm and hinge line less than the length of the shell."

This is not a common species.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio, and Watson.

PTERINOPECTEN.

A. Surface with concentric undulations.
  b. Concentric undulations numerous, elevated into strong nodes in crossing the rays. *P. nodosus.*
  bb. Concentric undulations about six to ten, not elevated into nodes in crossing the rays. *P. undosus.*
AA. Surface without concentric undulations. *P. reflexus.*

Pterinopecten reflexus Hall.

Pl. XII, fig. 8.

P. reflexus Hall, Pal. N. Y., Vol. V, Pt. I, 1884, p. 58, Pl. 82, fig. 8.

Hall's original description.—"Shell of medium size, rhomboidal, moderately oblique; length one-sixth greater than the height; outline regularly curved to the posterio-basal margin, thence extending posteriorly. Left valve depressed convex; margin reflexed. Right valve unknown. Hinge line straight, extended posteriorly, exceeding the greatest length of the shell. Beak obtuse, low rounded, directed forward. Umbonal region convex subtending an obtuse angle. Posterior ear large flat, triangular, scarcely defined from the umbo; margin slightly convex; extremity obtuse. Anterior ear small, triangular, convex, limited by an undefined sulcus and a shallow byssal sinus; margin nearly straight; extremity obtuse. Test marked by fine rounded striae, alternating with finer lines; intermediate spaces flat. The same surface marking continued in a subdued degree upon the posterior ear, and somewhat more strongly on the anterior slope and anterior ear. Internal characters unknown."

In some specimens the surface is marked by numerous concentric lines of growth. This is a common species at the Pipe Creek localities.

Formation and locality.

Jeffersonville limestone; Bunker Hill, Pipe Creek Falls and Falls of the Ohio.

Pterinopecten undosus Hall.

Pl. XII, fig. 9.

The only specimen of this species which I have found is very poorly preserved. It is marked by six strong concentric undulations, which are crossed by closely arranged rounded striae.

Formation and locality.

Jeffersonville limestone; Bunker Hill.

Pterinopecten nodosus Hall.

P. nodosus Hall, Pal. N. Y., Vol. V, Pt. I, Pl. 82, fig. 13.

Hall's original description.—"Shell small, subrhomboidal, slightly oblique, form not fully known. Left valve very convex. Beak prominent, nearly erect. Umbonal region very prominent; the limits distinct on the anterior and obscure on the posterior side; subtending an acute angle. Posterior ear large, triangular; margin very slightly concave; extremity angular.

"Anterior ear not preserved in the specimen. Test thin marked (in a partially exfoliated specimen) by strong rounded rays with intermediate finer ones, and fine concentric undulating, elevated striae, with numerous concentric undulations which increase in frequency from the beak to the margin, and on crossing the larger rays, are elevated into strong nodes. On the posterior ear the rays are fine, equal and continuous. Interior characters unknown.

"This species is described from an imperfect specimen of the left valve, but it is so remarkable in its nodose undulations that it is readily distinguished from every other form."

This species is known only by the type specimen.

Formation and locality.

"Corniferous limestone"; Falls of the Ohio.

Actinopteria boydi (Conrad).

Pl. XIII, fig. 2.

A. boydi Hall, Pal. N. Y., Vol. V, Pt. I, p. 113, Pl. 19, figs. 2-24, 26-30; Pl. 84, figs. 16, 17.

Hall's description.—"Shell of medium size, rhomboidal; barely ovate, varying in proportions, the longitudinal axis at an angle with the hinge line of from 45 degrees to 60 degrees; length varying from nearly equal to one-fourth greater than the height; margins regularly rounded below, straight and nearly vertical for a short distance in front; post-basal side extended. Valves convex, the right valve a little less convex than the left. Hinge straight from the anterior side of the beak to the posterior extremity. Beak anterior, acute, prominent, inclined forward, rising above the hinge in the left valve. Umbonal regions prominent, subtending an acute angle. Ear short, oblique, limited by a deep but not sharply defined sulcus. Wing large, triangular not distinctly separated from the body of the shell. Margin concave; extremity acute. In the right valve the ear is somewhat more extended, the sulcus is not strong, but the byssal sinus is

marked; the wing is proportionally larger and usually more acute at the extremity. Test thick; the left valve in well preserved specimens, is marked by numerous strong simple, sharp rays, which are continuous from the umbo to the margin with rarely intercalated finer rays, crossed by regular sharp, elevated concentric lamellae. On the wing the rays are more subdued while the concentric lamellae are strong. The ear is marked only by the crowded concentric striae. On the right valve the radii are obsolete on the body and well marked on the wing, and the lamellose expansions are conspicuous. In some cases they appear as undulating elevated lamellae. Pallial line extending parallel to the margin of the shell and terminating in a muscular impression on the posterior slope. A small muscular impression is also seen just in front of the beak, and obscure indications of one or two cardinal teeth. Ligamental area narrow, striated, marked by two or three slender grooves which are slightly divergent from the hinge line. One of the original specimens of *A. quadrula* (=*A. boydi*) has a length of 30mm, height and hinge line each 28mm. A similar specimen has length of 25mm, height and hinge line each 23mm."

This species occurs abundantly in certain layers at a few localities. Usually, however, it is entirely absent.

Horizon and locality.

Jeffersonville limestone; Pipe Creek Falls, Lancaster and Falls of the Ohio.

PTERINEA.

A.	Shell very large, wing not strongly defined.	*P. grandis.*
AA.	Shell not very large, wing strongly defined.	*P. flabellum.*

Pterinea flabella (Con.) Hall.

This species differs from *P. grandis* in its smaller size, more strongly defined wing and shorter form.

It is a rare species.

Horizon and locality.

Sellersburg beds; Lancaster and Falls of the Ohio.

Pterinea grandis Hall.

P. grandis Hall, Pal. N. Y., Vol. V, Pt. I, 1884, p. 91, Pl. 83, fig. 14.

Hall's original description.—"Shell very large, capacious, oblique, subrhomboidal, body broadly ovate; length about one-fifth greater than the height; margins regularly rounded, broad along the base,

and a little produced on the posterior side. Left valve convex. Right valve unknown. Hinge line straight, apparently somewhat less than the length of the valve, (imperfect in the specimen). Beak obtuse, prominent, directed forward. Umbonal region gibbous, subtending an angle of about 90 degrees. Wing large, triangular, not distinctly defined, margin rounded with a gentle concavity near the junction of the valve. Ear not observed. Test thick, marked by distant strong radii from the umbo to the base; the interspaces having alternate larger and smaller rays; crossed by concentric undulating lamellose striae of growth. Interior unknown.

"The specimen has a length of 120mm, height 100mm and the hinge line from the beak to the extremity of the wing, 95mm."

No other specimens besides the types have been found.

Formation and locality.

"Upper Helderburg limestone"; Scott County.

GLYPTODESMA.

A. Surface with strong radiating striae. *G. cancellatum.*

AA. Surface without radiating striae.

b. Limitation between the body and posterior wing strongly defined; shell not very robust and surface not strongly marked by the fascicles of striae. *G. erectum.*

bb. Limitation between the body and the posterior wing not strongly defined; shell robust and surface strongly marked by the fascicles of striae. *G. occidentale.*

Glyptodesma occidentale Hall.

Pl. XIII, figs. 4, 5; Pl. XIV, fig. 1.

G. Occidentale Hall, Pal. N. Y., Vol. V, Pt. I, 1884, p. 157, Pl. 15, fig. 12; Pl. 86, fig. 9.

Hall's description.—"Shell large, broadly ovate; body nearly erect; height and length about equal; margins regularly curved. Left valve very convex, gibbous on the umbo. Right valve unknown. Hinge line straight, equaling or greater than the length of the shell. Beaks anterior to the shell directed slightly forward, acute and prominent. Umbonal region gibbous, defined anteriorly by the broad sulcus and on the anterior side sloping abruptly to the wing. Anterior wing short, defined by a deep sulcus and a marked byssal sinus. Posterior wing large, depressed convex, much extended, joining the body of the shell below the middle, and defined only by the recurving of the striae; margin concave; extremity acute. Test thick marked by numerous fine striae of growth, which at intervals are

crowded into fascicles, producing an undulating surface. The striae are more closely arranged and become lamellose on the anterior part of the shell. On the posterior wing the striae are regular, and at distant intervals a single striae becomes sharply elevated. Interior unknown. The specimen of this species described has a length of 60mm; height 66mm, and hinge line equal to or greater than the length of the shell."

The right valve of this species is much less convex than the left; the umbonal region is moderately convex, while the lower half of the valve is nearly flat. The surface is somewhat rugose from the fascicles of striae, but less so than that of the left valve.

A cast of the interior shows a large posterior muscular impression near the middle of the posterior slope. From the lower anterior side of this impression the pallial line curves downward and forward, and then upward, terminating in the rostral cavity.

This is a very abundant species in the chert of the Sellersburg beds.

Formation and locality.

Sellersburg beds; Falls of the Ohio, Scipio, Paris Crossing, Lancaster, Charlestown, Hanover, and Bartholomew County.

Glyptodesma erectum Hall.

G. erectum Hall, Pal. N. Y., Vol. V, Pt. I, p. 153, Pl. 11, figs. 1-10; Pl. 12, figs. 1-3, 5-9; Pl. 13, figs. 1-4, 12-15; Pl. 25, figs. 14-17; Pl. 86, figs. 1-8; Pl. 87, figs. 1-3.

This species is most closely related to *G. occidentale*, and a study of a large series of specimens would probably show that the latter is a variety of *G. erectum*. *Glyptodesma erectum* differs from *G. occidentale*, according to Hall, in its less robust form, in being less orbicular, and less gibbous in the umbonal region; the surface is less rugose from the undulations of the fascicles of striae and the limitation between the body and the potserior wing is less strongly defined.

Horizon and locality.

Jeffersonville limestone; Scipio, Lancaster and Falls of the Ohio.

Glyptodesma cancellata Nettleroth.

G. cancellata Nett., Ky. Foss. Shells, 1889, p. 227, Pl. 5, fig. 1.

Nettleroth described this species from a specimen found in the "Corniferous limestone" at the Falls of the Ohio. No other specimens have been found so far as I know.

Leptodesma rogersi Hall.

Pl. XIII, figs. 3, 3a, 3b.

L. rogersi Hall, Pal. N. Y., Vol. V, Pt. I, p. 176, Pl. 21, figs. 1-9.

Hall's description.—"Shell of small or medium size, subrhomboidal; body ovate, very oblique; length greater than the height, anterior and basal margins broadly rounded; posterior margin extended and abruptly recurved. Valves equally convex above. Right valve somewhat depressed below, comparatively higher than the left. Hinge line straight, longer than the length of the shell. Beak subanterior, obtuse, nearly erect, prominent. Umbonal region gibbous, oblique. The anterior extremity is scarcely alate or auriculate, consisting of a rounded extension, straight above and highly sinuate at the base. Wing comparatively large, triangular, joining the body of the valve near the posterior extremity, defined by the crowding and curving of the concentric striae; margin nearly straight for five-sixths of its extent, then acutely recurving; extremity prolonged into a mucronate spine which extends beyond the posterior limit of the valve. In the right valve the wing is less deeply sinuate. Test thin, marked by closely arranged concentric striae, which at irregular intervals are crowded into fascicles, producing a gently undulating surface. On the wing the striae are closely arranged and just below the hinge line are turned backward along the spiniform extension of the wing. Interior unknown. Ligamental area narrow, several fine grooves parallel to the hinge."

All of my specimens are small; the largest measures 30/50 of an inch from the beak to the base, 24/50 of an inch in height and 30/50 along the hinge line to the base of the mucronate extension. The mucronate extension of the hinge line seen in the New York specimens has not been observed. This may be due to the imperfection of the specimens secured. This species has been found at but one locality, where it occurs abundantly in a limestone.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls.

Ptychodesma knappianum H. and W.

Pl. XV, figs. 2, 2a, 2b, 2c.

P. knappianum Hall & Whitfield, 24th Rep. N. Y. State Mus. Nat. Hist., 1872, p. 192.

Hall and Whitfield's original description.—"Shell obliquely ovate, compressed posteriorly, and more or less ventricose in the middle

and toward the front; hinge line short, beaks subterminal; anterior end truncated at right angles to the hinge line. Surface marked by fine concentric striae with more distinct laminae of growth. Ligamental area well developed, sublinear, deeply grooved on the sides, the grooves and intermediate ridges slightly inclined toward the hinge line on both sides of the apex. The area shows seven grooves and eight ridges on each valve; but these increase in number with the growth of the shell, and are therefore not of specific value. This shell bears much resemblance externally to some forms of Modiomorpha and Nyassa; but the deeply grooved ligamental area is a distinctive feature."

The hinge has about three short oblique hinge teeth just below the beaks, and two long teeth near the posterior end of the hinge, having a direction parallel with it. In the larger specimens the upper margins of the hinge area are usually distant, showing the deeply grooved area; the smaller specimens have the margins of the hinge area closely appressed and the area is not exposed.

Formation and locality.

Sellersburg beds; Charlestown and the Falls of the Ohio.

Schizodus contractus Hall.

Pl. XV, fig. 9.

S. contractus Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 451, Pl. 75, figs. 27, 28.

Hall's original description.—"Shell small, ovate, cuneate; length one-third greater than the height; basal margins regularly curving. Posterior extremity pointed, nasute below, obliquely truncate above. Cardinal line more than half the length of the shell. Anterior end short, regularly rounded. Valves regularly convex below, gibbous in the middle and above. Beaks at about the anterior third prominent, incurved, flattened. Umbonal slope distinctly angular, extending to the post-inferior extremity. Post-cardinal slope concave, marked by a narrow depression near the cardinal line. Surface marked by fine elevated sharp filiform concentric striae, which become fasciculate towards the margin; also sometimes marked by very fine radiating striae. Anterior muscular impressions strongly limited posteriorly. Two specimens measure respectively 14 and 15mm in length and 10mm in height."

This species is very rare. My collection contains only one specimen. It is much smaller than the specimens figured by Hall, measuring in length 32/50 of an inch and in height 34/50 of an inch.

In other respects it agrees with Hall's figures and description. The muscular impressions are situated near the beak, the anterior impression being slightly nearer the beak than the posterior.

Formation and locality.

Jeffersonville limestone; Newbern, Bartholomew County, and Lancaster.

PARACYCLAS.

A. Anterior end of shell produced and flattened, posterior slope marked by an oblique sulcus. *P. ohioensis.*

AA. Anterior end of shell not flattened, posterior slope without an oblique sulcus.

- **b. Beaks anterior, elliptical in shape. *P. elongata.***
- **bb. Beaks central or subcentral, circular or subcircular in shape.**
  - **c. Shell medium size, marked by strong subangular concentric ridges. *P. lirata.***
  - **cc. Shell large, marked by fine concentric striae, aggregated into fascicles at irregular distances. *P. elliptica.***

Paracyclas elliptica Hall.

P. elliptica var. occidentalis, Hall and Whitfield, 24th Ann. Rep. N. Y. State Mus. Nat. Hist., p. 189, 1872.

Hall and Whitfield's description.—"Shell orbicular, of medium size, nearly circular in outline, with regularly curving valves and small, closely appressed and approximate beaks, centrally situated. Cardinal border very slightly excavated just anterior to the beaks, but rounded and full behind. The sinus just within the posterior cardinal margin (so characteristic of the group) is but slightly developed. Surface marked by strong, sharp striae which are often developed into irregular concentric ridges."

This species is rather common in some localities.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Falls of the Ohio, Watson, Charlestown, Lexington, Pipe Creek Falls and Keysport.

Paracyclas lirata (Conrad).

Pl. XV, fig. 10.

P. lirata Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 441, Pl. 72, figs. 2-19; Pl. 95, fig. 19.

Hall's description.—"Shell of medium size, subcircular or broadly elliptical; length a little greater than the height; margins regularly rounded. Cardinal line short, less than half the length of the shell.

Valves moderately convex below, becoming gibbous on the middle and above. Beaks anterior to the center, small, appressed, rising but little above the hinge line. Post-cardinal slope not defined. Surface marked by fine concentric striae, and by strong subangular concentric ridges, which are more or less sharply defined, depending upon the condition of the specimen and the nature of the matrix in which the fossil is imbedded. Ligamental grooves distinctly marked and only moderately divergent from the cardinal margin.

"Four specimens measure respectively 15, 19, 25, and 29mm in length and 13, 18 and 25.5mm in height."

This is a common species in the "Cement rock" of southern Indiana.

Horizon and locality.

Sellersburg beds; Falls of the Ohio, Lexington and Charlestown.

Paracyclas elongata Nettleroth.

P. elongata Nett., Ky. Foss. Shells, 1889, p. 210, Pl. 2, fig. 8.

Nettleroth's original description.—"This shell resembles very closely *P. lirata* of Conrad, but differs from it greatly in form, so much so, that any one must distinguish the two species at the first glance. While *P. lirata* has almost the shape of a regular circle, this shell has the form of an ellipse, in which the larger axis exceeds the smaller one considerably. In this shell the width is only about three-fourths of the length. It is covered with strong concentric striae which are sharply marked, almost all parallel to each other and equidistant. The depression of the dorsal margin in front of the beaks is very conspicuous; the illustration does not show this at all or very faintly. The beaks are close to the anterior margin; the anterior slope is steep, while the posterior one has little fall. The size of this shell varies in different specimens; it agrees generally with that of *P. lirata*. Both valves are moderately convex. It differs from *P. lirata* by its elongate shape, and by the position of its beaks, which is subanterior, while the position of the beaks in *P. lirata* is almost central."

This species is known only from Nettleroth's description.

Formation and locality.

Sellersburg beds; Clark County.

Paracyclas ohioensis (Meek).

Pl. XV, figs. 1, 1a, 1b.

Lucina (Paracyclas) ohioensis Meek, Pal. Ohio, Vol. I, 1873, p. 199, Pl. 18, fig. 7.

Meek's description.—"Shell apparently not attaining a medium size, compressed, more or less nearly circular; beaks small, central, depressed nearly to the dorsal line, and contiguous; anterior margin rather abruptly compressed above, just in front of the beaks; hinge margin short and rounding into the posterior dorsal outline; surface ornamented with small more or less regular, concentric undulations, most strongly defined on the umbones and very fine lines of growth; posterior dorsal slopes of each valve marked by a strongly oblique sulcus, extending from the back part of the beaks to the upper part of the posterior margin, to which it imparts a slightly sinuous outline at its termination. Length, 0.46 inch; height, 0.42 inch; convexity, 0.18 inch."

This is one of our rarest species. I have seen but four specimens, which differ considerably from each other and also from Meek's figures in outline, but which probably belong to the same species.

Formation and locality.

Sellersburg beds; Falls of the Ohio and Burnsville, Bartholomew County.

Paracyclas octerlonii Nettleroth.

After examining the types of this species I am inclined to regard them as distorted specimens of *Paracyclas elliptica.*

Cardiopsis crassicostata Hall and Whitfield.

C. crassicostata Hall and Whitfield, 24th Rep. N. Y. State Mus. Nat. Hist., p. 188; 27th Rep. N. Y. State Mus. Nat. Hist., 1875, Pl. 12, fig. 9.

This species was described from specimens found in the "upper limestone" at Louisville, Ky. It doubtless occurs in southern Indiana, but I have not seen it.

NUCULA.

A. Beaks subcentral.
 b. Shell small, less than ¾ of an inch in length. *N. lamellosa.*
 bb. Shell large, more than one inch in length. *N. hanoverensis.*
AA. Beaks anterior.
 c. Surface marked by radiating striae which cross the strong concentric undulations. *N. lirata.*
 cc. Surface without radiating striae, marked by concentric striae.
  d. Anterior margin almost vertically truncate. *N. niotica.*
  dd. Anterior margin not vertically truncate.
   e. Anterior and posterior extremities pointed, height and depth of shell equal. *N. herzeri.*
   ee. Anterior and posterior extremities rounded, height greater than the depth.
    f. Shell subequilateral, triangular in form. *N. corbuliformis.*
    ff. Shell rhomboid, ovate in form. *N. neda.*

Nucula hanoverensis n. sp.

Pl. XIV, fig. 3.

Size and form as indicated by the figure. Valves not very gibbous. Beaks subcentral; the internal cast shows a broad depressed belt extending around the margin from the anterior end of the hinge line to the posterior extremity of the shell. Above this band the valves are moderately and uniformly convex. Strongly marked anterior and posterior muscular scars are located just inside the hinge line near each end of the shell. A small retractor scar occurs on the posterior side of the large anterior scar. The hinge line between the anterior and posterior muscular scars is crenulated by transverse teeth. The surface markings are unknown.

The specimen described was found by Mr. Taylor, of Hanover, in the Upper Devonian chert.

Formation and locality.

Jeffersonville limestone; Jefferson County.

Nucula herzeri Nettleroth.

N. herzeri Nett., Ky. Foss. Shells, 1889, p. 221.

Nettleroth's original description.—"Shell small, subtrigonal; very gibbous; length one and one-half the height; both terminal extremities very narrow, almost pointed; beaks prominent and closely in-

curved; situated about one-fourth of the whole length from the anterior end; basal margin in its main portion only slightly convex, even at its anterior end, where it joins the anterior margin, which is most prominent close to the basal line; at the posterior end the basal margin turns in a light regular curve upwards to the very narrow, often pointed posterior margin. The cardinal margin slopes in a straight line down to the posterior extremity, and with an inflected curve very abruptly to the anterior extremity; umbones very ventricose, making the thickness of the shell equal to its height.

"This species is associated with *Nuc. niotica* and *neda*, which it resembles in some points, but is easily distinguished from them by its elongate form, its pointed terminal extremities, and the equality between its depth and height. An average sized specimen of this species has the following dimensions: Length, one-half inch; height and depth, one-third of an inch."

This species was described by Nettleroth without figures from the "cherty layers of the hydraulic cement rock." I have not seen it.

Formation and locality.

Sellersburg limestone; Falls of the Ohio.

Nucula corbuliformis Hall?

Pl. XIV, fig. 5.

N. corbuliformis Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 319, Pl. 46, figs. (10, 11?), 24-34 (35-36-37?).

Shell subtriangular, moderately gibbous; cardinal line slightly arcuate, basal margin broadly rounded; anterior end gently rounded. Beaks not very prominent, incurved; a wide faintly marked depression extends from the umbones to the basal margin. A subangular arcuate umbonal ridge extends to the post-basal margin. Surface marked by fine concentric striae with varices of growth. The specimen measures in length 7/10 of an inch, in height 5/10 of an inch, and in thickness 3/10 of an inch.

This specimen differs from Hall's description and figures of this species in possessing a rather distinctly defined umbonal slope and a faint depression across the middle of the valves. It is therefore with some doubt that I refer it to *N. corbuliformis*.

Formation and locality.

Sellersburg limestone; Charlestown.

Nucula lirata Conrad.

This species is reported from the "Corniferous group" in Shelby County by John Collett.* I have not seen it.

Nucula neda Hall.

Pl. XIV, fig. 4.

N. neda Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 314, Pl. 45, figs. 3, 4.

Hall's description.—"Shell of medium size, rhomboid-ovate cuneate; length about one-fifth greater than the height; basal margin broadly rounded; cardinal margin sloping to the anterior and posterior extremities, which are abruptly rounded. Valves gibbous, with the umbones ventricose. Beaks a little more than one-third the length of the shell from the anterior end, prominent and incurved. The surface has been marked by fine, concentric striae. The cast shows strong anterior and posterior muscular impressions, with three or four umbonal muscular scars and a narrow protractor scar just within the cardinal line, and anterior to the posterior muscular area, as usual in the genus. The number of teeth can not be determined, but there are as many as six or eight on the posterior side, with a distinct ligamental cavity in the cast beneath the beak. The specimen described has a length of 21mm and a height of 17mm."

This is a rather common species.

Formation and locality.

Sellersburg beds; Charlestown, Falls of the Ohio.

Nucula niotica Hall.

Pl. XIV, figs. 6, 7.

N. niotica Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 313, Pl. 45, figs. 1, 2.

Hall's description.—"Shell small, obtusely subcuneiform; length a little greater than the height; basal margin regularly curving, rounded posteriorly; cardinal margin very oblique; anterior margin vertically truncate. Valves very gibbous. Beaks anterior incurved. Umbo prominent, umbonal slope very gibbous. Test very thick in the upper part, marked by fine even concentric striae, which are aggregated into fascicles of growth.

*11th Ann. Rep. Ind. Dept. Geol. and Nat. Hist., p. 71.

"The interior cast shows strong anterior and posterior muscular impressions and three distinct umbonal muscles; there are seven or more posterior and five anterior teeth in a specimen of medium size. An internal mould has a length of 17mm, and a height of 13mm. A specimen preserving the test has a length of 18mm, and a height of 16mm."

The specimen figured measures in length $\frac{3}{5}$ of an inch; in thickness 6/25 of an inch.

This is not an uncommon fossil.

Formation and locality.

Sellersburg beds; Clark County.

Nucula lamellata Hall.

Pl. XIV, fig. 2.

N. lamellata Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 320, Pl. 51, figs. 18-21; Pl. 45, fig. 13 (?); Pl. 93, fig. 7.

Hall's description.—"Shell small, elongate ovate, truncate behind; length twice the height; basal margin broadly curving, straight or slightly arcuate in the middle; posterior margin short, obliquely truncate. Cardinal line straight, directed somewhat upward toward the anterior. Anterior end large and regularly rounded. Valves gibbous with a broad flattened depression extending from the beaks to the base and sometimes slightly constricting the margin. Beaks subcentral or posterior to the middle of the shell, incurved, rising a little above the hinge line. Umbo gibbous. Umbonal slope obtusely subangular, extending from the beak to the post-basal extremity, declining abruptly to the cardinal line. Surface marked by regular strong, lamellose, concentric striae which appear to be made up of aggregations of extremely fine striae. Six or eight strong transverse teeth are preserved on each side of the beak. Three specimens measure respectively 9, 8 and 7mm in length, and 4.5, 4 and 3.5mm in height."

The only specimen which I have found agrees perfectly with the above description of the New York specimens, except in size. It is much larger, measuring 17/25 inches in length and 8/25 inches in height. The surface is marked by about 25 lamellose striae. Their indistinctness near the middle of the shell appears to be due to the state of preservation. The cast shows a strong anterior and posterior muscular scar.

Formation and locality.

Jeffersonville limestone; in chert beds at Burnsville.

MODIOMORPHA.

A. Concentric striae prominent and regular. *M. concentrica.*
AA. Concentric striae not prominent, more or less irregular.
  b. Shell medium size, cardinal line straight or almost straight.
    c. Posterior end abruptly rounded, surface without strong varices of growth. Anterior end limited by a flattening of the valves extending from the beak to the margin. *M. recta.*
    cc. Posterior end greatly rounded, surface marked by strong varices or concentric zones, anterior end not limited by a flattening of the valves. *M. charlestownensis.*
  bb. Shell large, cardinal line usually arcuate.
    d. Anterior end extended, umbonal ridge not defined, shell rather elongate. *M. myteloides.*
    dd. Anterior end slightly extended, umbonal ridge gibbous and arcuate, shell rather broad.
      e. Cardinal margin nearly straight, anterior end rather wide below the beaks. *M. alta.*
      ee. Cardinal margin distinctly arcuate, anterior end narrow below the beaks. *M. affinis.*

Modiomorpha concentrica Hall.

Pl. XIV, figs. 10, 11.

M. concentrica Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 275, Pl. 34, figs. 9, 10; Pl. 35, figs. 1-5; Pl. 36, figs. 1-16 (17, 18?).

Hall's description.—"Shell of medium size, ovate, extremely variable in its proportions; length less than twice the height; basal margin often nearly straight, usually a little concave on the anterior third; posterior margin abruptly rounded below and more gently curving above; cardinal margin oblique in the prevailing forms, moderately arcuate, often nearly straight, subalate in many specimens. Anterior end produced beyond the beaks, abruptly rounded, sometimes nasute, limited by a broad depression extending from the beak to about the anterior third of the basal margin. Valves moderately convex, gibbous along the umbonal slope; the point of greatest convexity is about the anterior third of the length of the shell. Hinge line extending half or sometimes more than half the length of the shell. Beaks subanterior, small, sharply angular, appressed, directed forward. Umbonal region a prominent subangular elevation, extending obliquely from the beak toward the post-basal margin, usually dying out before the middle of the length of the shell. Test comparatively thick, strongly ornamented by regular concentric rounded or subangular striae, which become lamellose and coalescing on the anterior end of the valves, where they are less prominent. Anterior

muscular impression strong striated, situated just within the anterior margin, with a small retractor scar above it. Posterior impression large and shallow. Pallial line moderately impressed. Hinge furnished with a strong cardinal tooth just posterior to the beak in the left valve, and a corresponding depression in the right valve. No proper lateral teeth have been observed, but the cardinal margin is thickened and grooved from the beak backward about half the length of the cardinal line."

This species is rare. I have seen no perfect specimens of it.

Formation and locality.

Sellersburg beds; Watson, Charlestown, Lexington and Falls of the Ohio.

Modiomorpha charlestownensis Nettleroth.

M. charlestownensis Nett., Ky. Foss. Shells, 1889, p. 218, Pl. 5, figs. 7, 8 and 9.

This shell was described by Nettleroth from the "Hydraulic limestone" (Sellersburg beds) in Clark County. I have not seen it. It is closely related to *M. concentrica*, according to Nettleroth, from which it differs in its elongate form, greater gibbosity, its linguiform posterior end and the marked concentric zones on its surface.

Modiomorpha myteloides Con.

M. myteloides Hall, Pal. N. Y., 1885, Vol. V, Pt. I, p. 277, Pl. 37, fig. 2; Pl. 38, figs. 1-16.

I have not recognized this species in my collection, but Nettleroth reports it from Watson's Station, Clark County, associated with *M. concentrica* and *M. affinis.*

Modiomorpha affinis Hall.

Pl. XIV, fig. 9.

Shell large, gibbous, cardinal line arcuate, basal margin straight; beaks closely incurved, not prominent; anterior end short and regularly rounded. Umbonal ridge rounded, curved slightly upwards. Valves gibbous in the middle and upper part, nearly flat between the middle and basal margin anterior to the umbonal ridge.

The only specimen which I have seen measures in length 2⅝ inches, height 1½ inches; thickness 1 1/16 inches.

Formation and locality.

Sellersburg beds; Clark County.

Modiomorphora alta Hall.

Pl. XIV, fig. 8.

M. alta Hall, Pal. N. Y., 1885, Vol. V, Pt. I, p. 278, Pl. 37, figs. 1, 2 (4-6?), 7-12, 15, 16; Pl. 80, fig. 7.

Hall's description.—"Shell larger than the medium size, broad rhomboid ovate; length one-third greater than the height; the basal margin for two-thirds of its length from the anterior curve is nearly straight, varying from slightly concave to nearly straight, abruptly curving at the post-basal extremity, and continuing to the post-cardinal margin in an oblique, gently curved outline. In some examples the posterior margin is regularly curved, cardinal margins sometimes forming a nearly straight line, usually gently arcuate. In some examples the posterior margin is regularly curved, cardinal margin sometimes forming a nearly straight line, usually gently arcuate. Anterior end produced beyond the beak from one-sixth to one-fourth the length of the shell, obliquely truncated, obtuse, rounded below; its greatest extension is below the middle of the shell. Valves convex gibbous on the umbonal and medial portions of the shell; the umbonal ridge is gibbous and arched upward; the point of greatest convexity is about the middle of the shell or a little posterior. The depth of both valves is equal to two-thirds of the height of the shell. Hinge line straight, oblique, extending for less than half the length of the shell. Beaks rounded, somewhat appressed directed forward. Umbonal region not strongly defined, depressed anteriorly, becoming gibbous in the middle of the shell, gradually merging into the general contour in the posterior portion. Test of moderate thickness, marked by irregular concentric striae which become fasciculáte and produce strong concentric ridges at irregular intervals. The surface is marked by fine vascular lines similar to those referred to in *M. myteloides.* The anterior muscular impression is situated close to the anterior margin of the shell, with a small retractor scar above it. Other characters of the interior are unknown. The type specimen has a length of 68mm, and a height of 46mm."

This species is rare. The specimen figured measures in length 2 1/10 inches, height 1⅗ inches, thickness ⅗ of an inch. Two of these have the shell of *Crania sheldoni* attached.

Formation and locality.

Sellersburg beds; Watson, Charlestown and Falls of the Ohio.

Modiomorphora recta Hall

M. recta Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 286, Pl. 35, fig. 9.

I have not seen this species. It was described by Hall from specimens found in the "cherty layers of the Hamilton group," (Sellersburg beds), in Clark County.

Sanguinolites? sanduskyensis Meek.

Pl. XVI, figs. 6, 6a.

S. sanduskyensis Meek, Pal. Ohio, Vol. I, 1873, p. 209, Pl. 18, fig. 3.

Meek's description.—"Shell approaching longitudinal-oblong or trapezohedral outline, moderately convex, a little more than twice as long as high, and slightly narrower anteriorly than behind; cardinal margin straight, equaling about three-fifths the entire length; basal margin nearly straight or a little sinuous towards the front, and subparallel to the hinge, or slightly ascending anteriorly along its entire length and rounding up a little more gradually into the front than behind; posterior extremity compressed, obliquely truncated above and rather narrowly rounded to the base below; anterior side very short, sloping rather abruptly from the beaks above, and narrowly rounded at the middle; beaks depressed nearly or quite to the hinge line, compressed and placed near the middle of the anterior third; posterior umbonal slopes not regular or even prominently rounded, surface only showing a few regular furrows and slight undulations of growth, most distinct below the middle of the valves. Length 2.70 inches; height at the posterior end of the hinge, 1.20 inches; do under the umbones, 1.04 inches; convexity about 0.52 inch."

The specimens which I have referred to this species are much smaller than the specimens figured by Meek; the largest has a length of 1⅛ inches. They occur as casts in the chert. A very faint cincture extends from the beak diagonally to the basal margin; there is a muscular scar below the beak, just inside the anterior margin. This shell is rather rare.

Formation and locality.

Jeffersonville limestone; Burnsville and Newbern, Bartholomew County.

GRAMMYSIA.

A. **Cincture extending from the beaks to basal margin strongly marked.** *G. subarcuata.*

AA. **Cincture extending from beaks to basal margin not well defined or obsolete.**

- b. **Posterior slope with fine radiating striae.** *G. arcuata.*
- bb. **Posterior slope without radiating striae.** *G. secunda* **var.** *gibbosa.*

Grammysia subarcuata Hall ?.

Pl. XV, fig. 3.

A single imperfect specimen is referred to this species with some doubt. The shell is gibbous, width to height as two to three, beaks prominent; a faint cincture extends from the beaks to margin of shell; surface marked by strong concentric undulations.

Formation and locality.
Sellersburg beds; Charlestown.

Grammysia arcuata Hall.

G. arcuata Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 373, Pl. 61, figs. 1-9; Pl. 63, fig. 6; Pl. 93, fig. 27.

This species has been recognized by Hall "in the cherty layers above the Corniferous limestone at the Falls of the Ohio." I have not seen it.

Grammysia secunda var. *gibbosa* H. and W.

G. secunda var. gibbosa H. & W., 24th Rep. N. Y. State Mus. Nat. Hist., 1872, p. 199; 27th Rep. N. Y. State Mus. Nat. Hist., 1875, Pl. 12, figs. 7, 8.

I have not been able to secure specimens of this shell. It has been described by Hall and Whitfield from "the Hydraulic limestone at the Falls of the Ohio."

GONIOPHORA.

A. Shell marked by radiating striae. *G. truncata.*
AA. Shell without radiating striae. *G. hamiltonensis.*

Goniophora hamiltonensis Hall.

Pl. XVI, figs. 4, 5.

G. hamiltonensis Hall, Pal. N. Y., Vol. V, Pt. I, p. 296, Pl. 43, figs. 8-15, 17-21.

Shell of medium size, trapezoidal, length a little more than twice the height; basal margin nearly straight, sometimes sinuate at the terminus of the sinus. Posterior margin obliquely truncate. Cardinal line usually parallel with the basal margin, sometimes slightly arcuate. Valves convex below the umbonal ridge, and concave above it. Umbonal ridge strongly defined and angular, extending from the beaks to the post-basal extremity in a nearly direct line. A broad undefined sinus which is sometimes obsolete extends from the beak

to the anterior basal margin. Surface marked by strong concentric striae. Cast shows a deeply impressed muscular scar near the anterior margin.

This species is not uncommon in the condition of casts in the chert near the top of the Devonian limestone.

Formation and locality.

Jeffersonville limestone; Newbern and Burnsville, Bartholomew County.

Goniophora truncata Hall.

G. truncata Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 298, Pl. 42, figs. 9-10; Pl. 44, figs. 1-5.

I have not seen this shell. Nettleroth reports it to occur very rarely in the "Corniferous limestone" at the Falls of the Ohio.

CYPRICARDINIA.

A. Shell with concentric lines of growth. *C. cataracta.*
AA. Shell with lamellose concentric striae.
 b. Concentric lamellose undulations very prominent with faint radiating striae crossing them. *C. indenta.*
 bb. Concentric lamellose striae faint, not marked by radiating striae. *C. cylindrica.*

Cypricardinia indenta Conrad.

Pl. XV, figs. 8, 8a.

C. indenta Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 485, Pl. 79, figs. 6-16, 23; Pl. 96, fig. 2.

Hall's description.—"Shell of medium size, subrhomboid-ovate; length more than one-third greater than the height; basal margin nearly straight, slightly sinuate anterior to the middle. Posterior extremity abruptly rounded below and obliquely truncate above. Cardinal line straight oblique. Anterior end very short, rounded below. Right valve convex, often extremely gibbous. Left valve usually depressed-convex below and posteriorly, becoming moderately gibbous in the umbonal region. Beaks nearly anterior small and appressed, rising but little above the hinge line. Cincture distinct upon the right valve, less marked upon the left valve. Surface marked by extremely fine concentric striae, and by unequally distant but somewhat regular, lamellose, imbricating, concentric undulations; and in well preserved specimens the entire surface is marked by fine striae which radiate from the apex of the shell, and in some conditions of preservation the surface shows a second set of striae vertical to the direction of the lamellae."

This is a common species in northern Indiana. The specimens appear to be smaller than the New York representatives of the species, seldom exceeding a half inch in length. Nearly all of the shells are exfoliated and do not show the finer surface markings; a few, however, show traces of the radiating striae.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls, Bunker Hill and Falls of the Ohio.

Cypricardinia cataracta Conrad.

This species is reported by Nettleroth to occur in the "Corniferous limestone at the Falls of the Ohio."

Cypricardinia? cylindrica H. and W.

C. cylindrica H. W., 24th Reg. Rep. N. Y., 1870, p. 190.

C. cylindrica H. W., 27th Reg. Rep. N. Y., 1875, Pl. 2, figs. 5, 6.

Hall and Whitfield's original description.—"Shell cylindrical, extremities rounded, height little more than the depth, and rather more than twice as long as high; beaks nearly terminal, rounded and incurved; left valve scarcely less convex than the opposite; umbonal slope slightly angular. Surface marked by faint distant concentric lamellose lines.

"The specimen described is essentially a cast preserving a portion of the shell on one side. This species is more elongate and cylindrical, less arcuate, and more equivalve than *C. inflata*. The lamellose striae have never been so strong and are more distant."

I have not seen this species.

Formation and locality.

Sellersburg beds; Clark County.

CONOCARDIUM.

A. Umbonal slope angular, shell not distinctly constricted in front, radiating plications on ventricose portion of shell numerous. *C. cuneus.*

AA Umbonal slope rounded, shell distinctly constricted in front, about six radiating plications on the ventricose portion of the valve. *C. ohioense.*

Conocardium ohioense Meek.

Pl. XV, fig. 7.

C. ohioense Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 411; Pl. 68, figs. 2, 3.

Hall's description.—"Shell small, ovate, subtrigonal, ventricose behind the middle of its length; length one-third greater than the

height. Posterior end prominent, produced in the middle and sloping abruptly to the post-cardinal angle. Anterior end abruptly contracted in front of the middle and prolonged, nasute, with the extremity narrowly rounded. The body of the shell is marked by about six strong radiating plications on the ventricose portion of the valve, and on each side more numerous and smaller plications. The interspaces between the ribs are marked by lamellose concentric striae. A specimen of this species has a length of 15mm and a height of 10mm. This species differs from *C. cuneus* in being more narrowly ventricose, and the body of the shell marked by fewer plications, with a distinct constriction in front; the umbonal slope is more rounded and less oblique, while the posterior extremity is more produced than in the usual forms of *C. cuneus* and *C. trigonale*."

Miller described a new species in the 17th Indiana Geological Report, p. 94, under the name of *C. exigum*. The descriptions and figures together with a study of material from Bunker Hill indicate that the specimens described belong to *Conocardium ohioense*.

Conocardium cuneus Hall.

Pl. XV, Figs. 4, 5.

C. cuneus Hall, Pal. N. Y., Vol. V, Pt. 1, 1885, p. 409, Pl. 67, figs. 1-32; Pl. 68, figs. 1, 4-16; Pl. 94, figs. 11-12.

Hall's description.—"Shell large angularly subovate, or trigonal in outline; length less than twice the height; basal margin greatly curving from the post-inferior extremity to the anterior end. Posterior extremity abruptly truncate, produced into a tubular extension along the cardinal line. Cardinal line straight, margins inflected towards the anterior end. Anterior end more or less attenuate, with the margins gaping before reaching the extremity. Valves gibbous. Beaks subcentral prominent and closely incurved over the hinge line. Umbonal slope angular, usually strongly defined, extending to the post-inferior extremity. Post-cardinal slope flat or concave. Test thick, composed of two distinct layers. Surface marked by numerous radiating plications and intermediate arching lamellose concentric striae on the body of the shell. The posterior slope is ornamented by curving radii extending from the beak to the posterior margin, with the interspaces marked by transverse lamellose striae. From the entire periphery of the umbonal ridge there extends a finely striated expansion of the shell, which increases in extent from the beaks downward and in old shells is supported anteriorly by a thickening of the shell along the basal margins, which often obliterates

the radii. At the junction of these thickened portions, along the base of the valves, the shell is excavated, leaving a tubular opening extending backward from the post-inferior extremity. Valves crenulated along their margins. Anterior muscular impression elongate, deeply impressed, narrower behind. Four specimens measure respectively 60, 47, 43 and 21mm in length and 30, 33, 26 and 13mm in height."

Hall recognizes the following three varieties of this species:

Var. attenuatum Conrad. In this variety the surface is marked by numerous uniform fine radii, and the posterior extremity is not abruptly truncated. This is probably the young of *C. cuneus*.

Var. trigonale Hall. The specimens from the Corniferous limestone were originally described under this name as a distinct species.

Var. nasutum Hall. This variety is characterized by fewer radii than the characteristic forms of *C. cuneus;* it is short and triangular in form, broad and abruptly truncated behind, abruptly truncated in front with the anterior end nasute.

The interior of this shell is marked by strong flat or rounded ribs which are continued slightly beyond the edge of the shell, giving the crenulated margin.

Miller has described a Conocardium from Bunker Hill under the name of *C. parvulum.* It appears from the description and figure to be a variety of *C. cuneus.* The umbonal slope in this variety is nearly at right angles to the cardinal line instead of making an oblique angle to it as in typical specimens of *C. cuneus.*

Formation and locality.

Jeffersonville limestone; Falls of the Ohio, Hanover, Bartholomew County and Bunker Hill.

CLINOPISTHA.

A. **Shell with radiating striae running from the dorsal to the basal margin.** ***C. striata.***

AA. **Shell without radiating striae running from the dorsal to the basal margin.**
- b. **Length about twice the height; no radiating striae.** ***C. subnasuta.***
- bb. **Length less than twice the height, with obscure radiating striae toward the basal margin.** ***C. antiqua.***

Clinopistha subnasuta Hall and Whitfield.

C. subnasuta Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 512, Pl. 51, figs. 32, 33; Pl. 95, fig. 31.

Hall's description.—"Shell small, narrowly subelliptical, nearly straight on the basal side; length about twice the height. Basal margin nearly straight, curving abruptly to the anterior and more

gently to the posterior end. Posterior extremity rounded. Cardinal line gently arcuate. Anterior end short, subnasute, declining from the beaks and narrowly rounded below. The place of the lunule is occupied by a fold or callosity which is distinctly limited by the margins of the valves. Valves moderately convex below and posteriorly gibbous in the umbonal region. Beaks at about the anterior third, small, closely appressed. Umbonal slope convex, not defined. Test thin. Surface marked by somewhat regular fine thread-like striae of growth, which, in the perfect condition of the shell, may have been lamellose, and are fasciculate on some individuals. The hinge shows some appearance of having been crenulated, but the condition of the specimens is such as not to admit of positive determination. Muscular impressions distinct. Pallial line entire, marked in the cast by a series of radiating pustules. Three specimens measure respectively 21, 26 and 27mm in length and 12, 13 and 13mm in height."

This is not a common species.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Watson, Lancaster and Pipe Creek Falls.

Clinopistha antiqua Meek.

Pl. XVI, fig. 3.

C. antiqua Meek, Pal. of Ohio, Vol. I, p. 208, Pl. 18, fig. 5a, b.

Meek's description.—"Shell very thin, transversely suboval gibbous, with flanks along the middle near the lower margin somewhat flattened or slightly concave; more than half as high as long; anterior or longer side regularly rounded in outline; posterior sloping above from the beaks to the narrowly rounded extremity, which is most prominent below the middle; basal margin straightened or broadly sinuous along the central region and rather abruptly rounded up at the extremities; beaks depressed nearly or quite to the dorsal outline, and placed about half way between the middle and the posterior extremity; dorsal outline nearly horizontal and parallel to the base in front of the beaks, but rounding regularly into the anterior margin. Surface merely showing moderately distinct lines of growth, with some obscure traces of radiating striae, where a little worn near the base; these last mentioned markings being more distinct on the internal cast. Length 0.22 inch; height 0.51 inch; convexity 0.39 inch."

I have seen but one specimen of this species, which differs from Meek's description only in being less gibbous.

Formation and locality.
Sellersburg beds; Clark County.

Clinopistha striata Nettleroth.

C. striata Nett., Ky. Foss. Shells, 1889, p. 200, Pl. 4, figs. 1-2.

Nettleroth's original description.—"Shell of medium size, transversely subelliptical; length not quite twice the width or height, and thickness about one-half the height; beaks small and closely appressed in the level of the dorsal margin and situated about two-thirds of the whole length from the anterior extremity; basal margin slightly convex in the central half but curving regularly but rapidly into the terminal margins. Dorsal margin straight and almost parallel with the central portion of the basal one; at its anterior end it curves down into the anterior margin, which appears to be regularly rounded; posterior end slopes down from the beaks to a somewhat pointed posterior extremity, which is most prominent a little below the middle height of the shell. Both valves are moderately convex. The surface is marked by very peculiar radii, which apparently run from the basal margin to the dorsal one, across the valves, but which make near the dorsal line a rapid deflection into the direction of the beaks. These radii are low and flat and have a faint but plainly observable depressed line in their middle, a feature which I have never noticed in any other shell. Their interspaces are large, from three to four times their own width; in some of these interspaces there is a smaller intermediate line. This species has the general features of *Clinopistha subnasuta* and *antiqua* except its peculiar surface markings and its greater size."

I have not seen this species.

Formation and locality.
Sellersburg beds; Clark County.

Solemya (Janeia) *vetusta* Meek.

Pl. XVI, figs. 1, 1a, 1b, 2.

S. (Janeia) vetusta Hall, Pal. N. Y., Vol. V, Pt. I, 1885, p. 46, Pl. 47, figs. 53-55; Pl. 94, fig. 10.

Hall's description.—"Shell of medium size, elongate elliptical; length more than twice the height; basal margin very gently curved. Posterior extremity very gently rounded. Cardinal line nearly straight or gently arcuate. Anterior end large, narrower than the posterior,

rather abruptly rounded at the extremity, carrying on its upper margin a distinct fold. Valves moderately convex below, scarcely gibbous in the upper portion. Beaks inconspicuous, situated anterior to the middle. Surface marked by regular distant lamellose, undulating concentric striae, which are crossed by distant radiating lines, between which the concentric striae curve downward."

Exfoliated shells show their interior to be marked by radiating striae which are most distinct towards the posterior end. The faint radiating lines which cross the concentric striae where the undulations bend upwards are sometimes indistinctly developed or wanting. They are usually confined to the middle portion of the shell where the undulations are most pronounced. This species is rare.

Formation and locality.

Sellersburg beds; Watson and Falls of the Ohio.

GASTROPODA.

BELLEROPHON.

A. Dorsum sharply carinate. *B. curvilineatus.*
AA. Dorsum not sharply carinate.
- b. Shell with strong revolving striae.
  - c. Transverse striae distinct, strongly ventricose, width greatly exceeding the length. *B. leda.*
  - cc. Transverse striae obsolete or indistinct, not strongly ventricose, width not greatly exceeding the length. *B. lyra.*
- bb. Shell without revolving striae.
  - d. Outer volution greatly expanded at the aperture, prominent part marked by strong costae with fine striae between. *B. patulus.*
  - dd. Outer volution not greatly expanded at the aperture; surface marked by subregular transverse striae. *B. pelops.*

Bellerophon leda Hall.

Pl. XXI, figs. 4, 5.

B. leda Hall, Pal. N. Y., Vol. V, Pt. II, p. 110, Pl. 23, figs. 2-16.

Hall's description.—"Shell subglobose, often a little flattened upon the dorsum; body whorl ventricose, very rapidly expanding. Aperture abruptly spreading, broadly sinuate in front and sometimes with a deeper notch in the middle, the margin gently recurved, joining the volution a little on the ventral side, where it is thickened, somewhat abruptly curving over and partially enclosing the small umbilicus, and extends in a callus over the columellar lip, which is sometimes distinctly striato-pustulose.

"Surface marked by strong longitudinal or revolving striae, which alternate in size, are sometimes fasciculate, and often finer and more numerous on each side of the dorsal band than on the lateral portions of the shell. The revolving striae are cancellated by finer, subequal, thread-like transverse striae. The dorsal band is narrow, rarely elevated or sometimes scarcely raised above the surface, and usually flat or slightly concave, the concentric striae making an abrupt retral curve upon it in crossing. The band is likewise usually marked by one, two, three or more revolving striae finer than those on the sides of the shell, and sometimes quite obscure." This shell is usually found in an exfoliated condition. It is rather common in the chert of the Upper Devonian at some localities.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Falls of the Ohio and Newbern.

Bellerophon pelops Hall.

Pl. XXI, fig. 7.

B. pelops Hall, Pal. N. Y., 1879, Vol. V, Pt. II, p. 95, Pl. 22, figs. 7-13.

Only a few imperfect specimens of this species have been seen. They show the slender dorsal band and subregular transverse striae which characterize this species. Hall regards this species as identical with Meek's *B. propinquus.*

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls, Charlestown, and Newbern.

Bellerophon patulus Hall.

Pl. XXI, fig. 7.

B. patulus Hall, Pal. N. Y., 1879, Vol. V, Pt. II, p. 100, Pl. 22, figs. 17-30; Pl. 24, figs. 3-6.

This species has been observed only in the form of the interior casts. The great expansion of the outer volution of this species is its chief distinguishing characteristic. In a specimen in Mr. Taylor's collection the outer lip has a transverse width of one and four-tenths inches and a longitudinal width of one inch. The height of the shell measured from the plane of the margin of the outer lip is five-tenths of an inch. According to Hall, "The surface on the expanded part of the outer volution is marked by fine close concentric striae, which are sometimes crowded in fascicles, giving an undulating surface; the posterior prominent part of the volution is marked on the back, and

partially on the sides, by strong even arching costae, which are more abruptly and sometimes subangularly curved on the dorsal line. These costae sometimes continue for half the length of the volution anteriorly, gradually becoming obsolete on the middle and sides, and are never seen upon the broad expansion of the shell. The spaces between these costae are marked by fine close concentric striae, and in well preserved specimens, extremely fine revolving striae are sometimes visible. The costae become finer or obsolete as they approach the umbilicus, and the surface is marked only by the fine striae of growth."

Formation and locality.

Jeffersonville limestone; Hanover, Charlestown and Shelby County and Falls of the Ohio.

Bellerophon lyra Hall.

B. lyra Hall, Pal. N. Y., 1879, Vol. V, Pt. II, Pl. 23, figs. 1, 17-20.

This species has not been seen by the writer. Hall reports having seen only one specimen, which he figured (fig. 1, Pl. 23).

Formation and locality.

"Hamilton; Falls of the Ohio."

Bellerophon curvilineatus Con.

Pl. XXI, figs. 1, 1a.

B. curvilineatus Hall, Pal. N. Y., 1879, Vol. V, Pt. II, pp. 94-95, Pl. 22, figs. 1-6.

Hall's description.—"Shell discoidal. Volutions four or five compressed and sharply carinated on the back, each one embracing about half the width of the preceding one, the last scarcely more ventricose than the preceding, and bending almost rectangularly at the umbilical edge. Aperture triangular, acute at the anterior margin, which is deeply sinuate; the curvature of the peristome from the umbilical side receding about one-quarter of a volution to the dorsal line. The inner margins of all the volutions are exposed in the cavity of the umbilicus.

"Surface marked by fine striae of growth, which follow the curvature of the peristome, making a retral curve of about a quarter of a volution; often slightly fasciculate, but sometimes the striae are in regular fascicles of about six or seven finer ones, with a fine sharply elevated finer one supporting them. The dorsum is sharply carinate."

I have seen but two or three specimens of this species. The smallest has a diameter of 2/10 of an inch. They are covered by fine striae which vary somewhat in strength. In crossing the dorsal carina the striae become extremely fine.

Formation and locality.

Jeffersonville limestone; Newbern and Hope, Bartholomew County.

Bellerophon sp.

Pl. XXI, fig. 3.

The specimen here figured is from Mr. Green's collection. I have not been able to identify it with any of the species described.

The anterior part of the outer volution, which is not shown in the figure, has a rugose appearance, due to coarse transverse, somewhat wavy or interrupted striae. These are separated by rather wide interspaces, and arch backward from the umbilicus to the dorsal band which is imbricated by them.

Formation and locality.

Sellersburg beds; Charlestown.

PLATYOSTOMA.

A. Form distinctly subturbinate or cone-shaped.
  b. Spire elevated. *P. turbinata.*
  bb. Spire depressed. *P. turbinata* var. *cochleata.*
AA. Form not distinctly turbinate or cone-shaped.
  c. Spire depressed, nearly flat on top. *P. lineata* var. *callosa.*
  cc. Spire moderately elevated.
    d. Volutions enlarging rapidly to the outer volution which is very ventricose. *P. lineata.*
    dd. Volutions enlarging gradually to the outer volution which is not very ventricose. *P. pleurotoma.*

Platyostoma pleurotoma Hall.

Pl. XX, fig. 6.

P. pleurotoma Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 30, Pl. 9, figs. 31-35.

Hall's description.—"Shell rotund, subturbinate. Spire depressed; volutions rounded, gradually enlarging, and the last one much expanded. Aperture broadly oval, and extended below; peristome more or less sinuous, and on the columellar side, extended below in a thickened and slightly contorted callosity.

"Surface finely striated with concentric and revolving striae, the latter conspicuous and the former scarcely perceptible. In one speci-

men a distinct narrow band marks the suture line; and in another, a narrow carina marks the periphery, giving the aspect of *Pleurotomaria*."

One specimen in the collection of Mr. G. K. Green is referred to this species. The striae on the lower two-thirds of the body whorl arch sharply from the umbilicus to a line extending nearly around the body whorl, which is very slightly elevated only near the aperture; above this line the striae bend gently backward and then forward to the suture. The revolving striae on the upper volutions are very fine and close and have a slightly wavy appearance. They are crossed by concentric striae.

Formation and locality.
Sellersburg beds; Charlestown.

Platyostoma sp.

Pl. XX, fig. 8.

Spire consisting of about two loosely coiled volutions; gradually enlarging from the apex. Body whorl disconnected from the apical whorl for about one-third of a volution. The periphery of body whorl rather sharply angular. Aperture subovate.

Surface marked by fine transverse striae and by very indistinct revolving striae.

This specimen differs from any species known to me in its disunited and angular body whorl. I am inclined to regard it, however, as an abnormal specimen and have not for that reason proposed a specific name for it.

Formation and locality.
Sellersburg beds; Charlestown.

Platyostoma lineata Conrad.

Pl. XX, figs. 1, 2, 2a, 3, 7.

P. lineata Hall, Pal. N. Y., Vol. V, Pt. II, p. 21, Pl. 10, figs. 1-21.

Hall's description.—"Shell subovate, approaching to subglobose. Spire elevated above the body whorl, though varying in degree; in some extreme varieties, on the same plane or below the outer volution.

"The shell with four or five volutions when entire, but seldom preserving more than three, the apex being usually imperfect. The outer volution usually very ventricose and regularly convex, a little depressed below the suture line (but not caniculate). Aperture sub-

orbicular in perfect specimens, sometimes subrhomboidal; outer lip thin, with a sharp entire margin; columellar lip thickened, folded, and reflexed over the umbilicus, which in adult specimens is entirely closed.

"Surface marked by fine, equidistant thread-like revolving striae, which are cancellated by fine concentric striae of about the same strength, but unequally distant; the latter sometimes bend abruptly backwards upon the back of the shell, indicating a sinus in the lip at some period of growth, and are frequently crowded in fascicles, giving a rugose character to the surface."

Mr. G. K. Green's collection contains several specimens of this species. They show considerable variation in the height of the spire, and in the character of the striae on the body whorl. In one specimen the transverse striae bend abruptly backward, producing a sharply defined ridge which extends half-way around the periphery of the body whorl. In others the striae arch sharply backward near the suture without producing a band or ridge.

Formation and locality.

Sellersburg beds; Charlestown.

Platyostoma lineatum var. *callosum* Hall.

Pl. XX, figs. 4, 4a.

P. lineatum var. callosum Hall, Pal. N. Y., 1879, Vol. V, Pt. II, p. 23, Pl. 10, figs. 22, 23.

This variety is based upon the depressed spire, slightly sinuate upper margin of the peristome and the thickened callus of the inner lip which characterize some specimens. It appears to be less common than the preceding type.

Formation and locality.

Sellersburg beds; Charlestown.

Platyostoma turbinata Hall.

P. turbinata Hall, Pal. N. Y., 1879, Vol. V, Pt. II, p. 27, Pl. 9, figs. 12-24.

Hall's description.—"Shell subturbinate, sometimes approaching a subglobose form. Spire depressed, or more or less elevated above the outer volution, sometimes nearly on the same plane; volutions three or four, rapidly expanding, the last extremely ventricose, with the lower part projected in the direction of the columella, which is much extended. Aperture subovate, broader above, narrowing and often extended below.

"Surface marked by fine subequal concentric striae, crossed by finer revolving striae; the former variously undulated upon the surface, indicating sinuosities in the aperture at different stages of growth. In older shells the striae become lamellose and often crowded in fascicles."

This species is included on the authority of Nettleroth.

Formation and locality.

"Corniferous limestone;" Falls of the Ohio.

Platyostoma turbinata var. *cochleata.*

P. turbinata var. cochleata Hall, Pal. N. Y., 1879, Vol. V, Pt. II, p. 28, Pl. 9, figs. 1-11.

Hall's description.—"Shell turbinate. Spire elevated conical, volutions about four or five; periphery of the last volution obtusely rounded or distinctly subangular, with a sinus in the margin of the aperture; the last volution sometimes becoming free near the aperture, as shown in figs. 5, 6 and 7. Aperture obliquely subovate or ovate; peristome sinuous, often with a deep notch in the upper margin, and sometimes continued in a columellar extension below.

"The specimens referred to this variety all agree in having an elevated spire, with rounded volutions above the last one, which is almost invariably subangular."

This variety is recorded by Nettleroth. It has not been seen by the writer.

Formation and locality.

"In the rotten hornstone" (Jeffersonville limestone?); Louisville, Ky.

Strophostylus varians Hall.

Pl. XX, figs. 5, 5a.

S. varians Hall, Pal. N. Y., 1879, Vol. V, Pt. II, figs. 16-31.

Hall's description.—"Shell obliquely subconical, or depressed subglobose. Spire moderately elevated; volutions about three or four symmetrically rounded above, and somewhat gradually enlarging to the last one, which is ventricose extending downward and forward. Aperture oval or suborbicular; peristome entire; the columellar lip usually expanded and spreading over the umbilicus, sometimes free and leaving the umbilicus exposed. Surface finely striate, with the peculiar thread-like striae visible on well preserved surfaces, while on the weathered portions they become lamellose; and on some specimens the surface is marked by peculiar waved and interrupted striae."

I have seen but two specimens of this shell, both in Mr. Green's collection. The smaller of these two is about one-third the size of the specimen figured. Over a part of the body whorl the striae are arched sharply backward, indicating a notch in the lip at one stage of growth. The columellar lip is attached to the umbilicus. In the specimen figured the umbilicus is exposed.

Formation and locality.

"Corniferous," (Nettleroth) and Sellersburg beds; Charlestown and Falls of the Ohio.

CALLONEMA.

A. Spire elevated.

- **b. Periphery of whorls flat.** *C. conus.*
- **bb. Periphery of whorls concave.**
  - **c. Shell large, usually more than an inch in height.** *C. lichas.*
  - **cc. Shell small, usually less than an inch in height.** *C. bellatulum.*

AA. Spire depressed or moderately elevated.

- **d. Surface marked by strong elevated striae.** *C. imitator.*
- **dd. Surface marked by very fine transverse striae.** *C. clarki.*

Callonema bellatula Hall.

C. bellatula Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 51, Pl. 14, figs. 10-15.

Hall's description.—"Shell subovoid conical; spire elevated and rapidly expanding below. Volutions about six or seven, the upper ones minute and somewhat gradually expanding to the third or fourth and more rapidly below, the last one being very ventricose, regularly rounded or obtusely subangular towards the base. Aperture apparently transverse, its extension below not fully known; columellar lip thickened, spreading above and extended anteriorly. Surface marked by regular elevated striae with about equal interspaces, which are slightly turned backwards from the suture and gently curved to the base of the volution, and on the last one curving over the periphery with equal strength, a portion becoming obsolete, and others coalescing and becoming stronger as they enter the umbilical depression."

The above description is based upon specimens from the Falls of the Ohio and Columbus, Ohio. The species is rare.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio and Hope.

Callonema conus n. sp.

Pl. XXIII, figs. 1, 1a.

Shell forming a nearly perfect cone, spire elevated. Volutions six or seven, perfectly flat between the sutures, the last one being sharply angular toward the base. Aperture subrhomboidal, character of the lip not well known, umbilicus exposed. Surface marked by fine regular striae which bend backward in passing from upper to lower sutures. Striae on the body whorl, crossing the angular base and continuing with equal strength to the umbilicus.

Only two specimens of this species have been found. The flat peripheries of the whorls and the angular base of the body whorl seem to characterize this as a type distinct from *C. bellatula*, to which it is most closely related.

Formation and locality.

Geneva limestone; Hope.

Callonema lichas Hall.

Pl. XX, fig. 11.

C. lichas Hall, Pal. N. Y., 1879, Vol. V, Pt. II, p. 52.

Hall's description.—"Shell obliquely conical ovate; spire elevated. Volutions about four or more, rounded upon the exterior, the earlier ones moderately expanding and the last ones becoming very ventricose. Aperture subovate extended below. Surface marked by fine even striae of growth which on the last volution continue over the periphery and disappear in the umbilicus."

This is not a common species.

Formation and locality.

Jeffersonville limestone?; Jefferson County.

Callonema imitator (Hall and Whitf.).

Pl. XXIII, fig. 5.

C. imitator Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 53, Pl. 14, figs. 16, 17.

Hall's description.—"Shell depressed hemispherical; spire moderately elevated, consisting of five or more rounded volutions, regularly increasing from the apex to the aperture, which is subcircular, its lower extension unknown, round below and broadly umbilicate; suture slightly depressed, not canaliculate and making the periphery of the preceding volutions. Surface marked by strong elevated

simple striae, which have a slight bend just below the suture and curve gently backward to the periphery, gradually increasing in strength from the apex to the outer volution, on the middle of which there are about twenty in the space of an inch. In one specimen, on the outer half of the volution, they become gradually obsolete or merge into the ordinary striae of growth."

Specimens of this shell which are well preserved are rare; interior casts which probably belong to this species are rather common at some localities.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio and Bunker Hill.

Callonema clarki Nettleroth.

C. clarki Nett., Ky. Foss. Shells, 1889, p. 175, Pl. 24, figs. 2, 4, 5.

Nettleroth's original description.—"Shell above medium size; subhemispherical; spire moderately elevated, more or less so in different shells, as shown by the two specimens illustrated, consisting of from three to five volutions. The volutions are regularly increasing from apex to aperture, which is subcircular or subquadrate; they are depressed convex on their upper side. The columella is much extended below. Suture small and shallow, between the upper volutions scarcely noticeable. The surface appears to the naked eye entirely smooth, but under a magnifier shows fine transverse striae, closely set between some stronger marked lines of growth. These striae and lines of growth extend from the suture down and backwards to the umbilical depression. The last volution or the body whorl, as it is also called, curves very abruptly at its middle, and slopes from there in a straight or slightly curved line to the inner lip of the aperture, making the lower half of the last volution either flat or only very little convex. The apex appears to be very minute in perfect specimens."

Formation and locality.

The types of this species were found in the Devonian chert east of Louisville. It has not been recognized in Indiana.

Isomena humilus Meek ?.

Naticopsis? (Isonema) humilis Meek, Pal. Ohio, Vol. I, 1873, p. 214, Pl. 19, figs. 1a, b, c.

Two or three imperfect specimens are referred with some doubt to this species.

Height of spire equals about two-thirds the width of shell. Volutions four, increasing rather rapidly in size. Surface marked by distinct lines of growth which are slightly arched. These are occasionally interrupted by strong wrinkles of growth. Aperture not preserved. Width of shell one and one-tenth inches.

Formation and locality.

Sellersburg beds; Charlestown and Lexington.

Bucania devonica Hall and Whitf.

B. devonica Hall & Whitf., 24th Rep. N. Y. State Mus. Nat. Hist., 1870, p. 191.

Hall and Whitfield's original description.—"Shell discoid, widely and equally umbilicate on the two sides; remaining volutions about four slightly embracing, vertically compressed, giving the transverse diameter a little more than twice the vertical diameter, lateral margins of the volutions obtusely angular toward the dorsal side. The surface has apparently been marked by several (three or four) revolving ridges or carinae on each side of the center or dorsum, which is gently concave; finer surface markings and aperture unknown."

This is not a common species. No specimens satisfactory for figuring have been found.

Formation and locality.

Kent, Charlestown, Falls of the Ohio and Bunker Hill.

LOXONEMA.

A. Surface smooth or indistinctly marked by striae.
  - b. Shell rather slender, spire tapering gently to the apex. *L. laeviusculum.*
  - bb. Shell rather robust, tapering rather abruptly near the apex. *L. teres.*

AA. Surface with strong transverse striae.
  - c. Striae fine, scarcely curved in crossing the whorl; whorl slightly constricted near the suture. *L. rectistriatum.*
  - cc. Striae coarse, strongly curved in crossing the whorl; the whorls not constricted near the suture.
    - d. Strongly constricted at the suture; whorls very convex. *L. hydraulica.*
    - dd. Not strongly constricted at the suture; volutions moderately convex. *L. hamiltoniae.*

Loxonema laeviusculum Hall.

L. laeviusculum Hall, Pal. N. Y., 1879, Vol. V., Pt. II, p. 131, Pl. 28, figs. 10-11.

Hall's original description.—"Shell elongate, subulate. Volutions about 12 in the entire shell, rounded and somewhat rapidly expanding to the last one, which is moderately ventricose. Suture close and simple. Aperture ovate, the columellar lip much extended below. Surface nearly smooth or marked by faint obsolescent striae, which are moderately curved over the convexity of the volution and become fasciculate on the lower side of the last one as they approach the columellar lip."

I have not seen this species. It was described from specimens obtained in the "limestone above the hydraulic beds." Nettleroth reports it to be associated with *L. hydraulicum* in the "cherty layers above the hydraulic limestone."

Formation and locality.

Sellersburg beds; Falls of the Ohio.

Loxonema sp.

A single broken cast of Loxonema in my collection differs specifically from any of these described from the Devonian and resembles rather closely *L. teres* from the Chemung. The lower whorls are marked by very strong angular plications, of which there are six or eight on the space of half the circumference of the shell. The upper whorls have more numerous and very much finer striae. The specimen is too imperfect to admit of a satisfactory specific description.

Formation and locality.

Devonian chert (Jeffersonville limestone?); Newbern.

Loxonema hydraulica Hall.

Pl. XVI, fig. 12.

L. hydraulica Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 44, Pl. 13, fig. 14.

Hall's description.—"Shell turreted. Volutions rounded, six in the length of one inch and a quarter from the base; greatest convexity about the middle of each; upper ones unknown. Suture deep, giving a constricted aspect at the junction of the volutions. Surface marked with distinct angular striae, bending gently backward from the suture to the periphery, and with a long forward curve to the base

of each volution; those of the last volution bending more abruptly backward and making a second abrupt retral curve to the columellar lip."

This species is very closely related, if not identical with *L. hamiltonae.* Not very common.

Formation and locality.

Sellersburg beds; Charlestown, Kent, Lexington and Falls of the Ohio.

Loxonema hamiltoniae Hall.

L. hamiltoniae Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 45, Pl. 13, figs. 15-17.

Hall's description.—"Shell elongate, subulate. Volutions moderately convex, about thirteen in the largest specimens known, very gradually increasing in size from the minute apex, the last one ventricose. Aperture ovate, narrowing below; columella extended. Surface marked by longitudinal, sharp, curving striae, which bend gently backward from the suture, and forwards toward the base of the volution, having the greatest curve near the middle, those of the last volution curving abruptly backward to the columellar lip. Striae separated by distinctly defined grooves which are a little wider than the ridges; the striae increasing in distance as the shell grows older."

A few specimens having a shallow suture and moderately convex volutions have been referred to this species.

Formation and locality.

Sellersburg beds and Jeffersonville limestone?; Watson, Burnsville, and Falls of the Ohio.

Loxonema rectistriatum Hall.

L. rectistriatum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 130, Pl. 28, fig. 9.

Hall's original description.—"Shell elongate terate. Volutions probably twelve or more in number, moderately convex, very gradually increasing in size, the last one being scarcely more convex than the preceding; each volution is distinctly contracted a little below the close suture, and then expanding gives the greatest convexity near the lower third. Suture line close. Aperture ovate, with the columella extending below. Surface marked by slender, gently curving longitudinal striae, which bend backward from the suture to the bottom of the constriction, and then continue to the base of the volution—those of the last one curving gently forward to the col-

umellar lip. The spaces between the striae are from once and a half to twice the width of the ridges."

The specimens which I have referred to this species are all very much smaller than the type figured by Hall. They agree with his description, however, in the nearly straight transverse striae, and the constriction of the whorls just below the suture line. It is not uncommon in the chert in some localities.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Burnsville and the Falls of the Ohio.

Loxonema? *teres* Hall.

L.? teres Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 42, Pl. 13, fig. 10.

Hall's description.—"Shell turretiform. Volutions seven or more, gradually enlarging from the apex, the last one moderately ventricose, and all gently rounded on the periphery."

The specimens referred to this species are like the type, casts which do not show any surface markings. The largest of these has a length of one and three-fifths inches. None of them show the entire spire."

Formation and locality.

Jeffersonville limestone; Newbern.

MACROCHEILINA.

A.	Last volution marked by a carina.	*M. carinatus.*
AA.	Last volution without a carina.	*M. hebe.*

Macrocheilina hebe Hall.

Pl. XXIII, fig. 2.

Macrocheilina hebe Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 32, Pl. 12, figs. 4-7.

Hall's description.—"Shell turreted subfusiform, length less than twice the diameter. Volutions five or six, upper ones minute, the last two ventricose; one-half the height of each volution showing above the suture. Shell thick on all parts, especially near the aperture. Aperture longitudinally suboval, somewhat pointed below. Surface marked by extremely fine lines of growth. Height of the longest individual seen, a little more than three-fourths of an inch.

The specimens which I have seen are not well enough preserved to show whether the fine lines of growth mentioned by Hall have

been present. In other respects, however, they agree closely with Hall's figures and descriptions of this species. This is a rare species.

Formation and locality.

Jeffersonville limestone; Bunker Hill and Newbern.

Macrocheilina carinatus Nettleroth.

Macrocheilus carinatus Nett., Ky. Foss. Shells, 1889, p. 180, Pl. 20, figs. 20-23.

Nettleroth's original description.—"Shell of medium size, turreted, subfusiform; length less than twice the diameter; volutions four or five, gradually increasing from the apex, last two ventricose, and the last one occupying one-half the length of the shell. Aperture not known; indications point to its being elongate. No surface markings are visible; they have been obliterated by the process of silification, to which our specimens were subjected. A peculiarity of this shell is the carina on the periphery of the last volution, as plainly shown in figures 20 and 23. It is in fact not a real carina but produced by the elevation of the lower half of the volution above the surface of the upper half. This species has some resemblance to *M. hebe,* but differs from it by the peculiar feature of its lower volution."

Formation and locality.

Sellersburg beds and "Corniferous limestone;" Falls of the Ohio and Lexington.

Murchisonia desiderata Hall.

Pl. XVI, fig. 8.

M. desiderata Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 89, Pl. 2y, figs. 1-3.

Hall's description.—"Shell elongate turretiform; spire somewhat rapidly ascending. Volutions ten or more, obtusely angular, flattened on their upper sides, and a little more convex below the spiral bend, the lower ones gradually enlarging; the greatest width of the last volutions about equal to the height of the two above, and scarcely more ventricose than the preceding one, except toward the aperture. Aperture somewhat elongate; the columellar lip thickened and bounded by a marked callosity.

"Surface marked by distinct concentric striae, which are sometimes raised in fascicles above the general surface of the shell, and bending gently back from the suture reach the spiral band, crossing which they bend forward more abruptly, making a gentle curve to the

suture below. The spiral band at about three-fourths of the width of the volution below the suture is simple, flattened or slightly concave, limited by narrow moderately elevated revolving lines, and marked by the retrally curving striae, which are less prominent upon it and the adjacent parts than near the suture. Suture close."

The specimen here figured is considerably larger than those figured by Hall. I have seen only one specimen in which any of the striae are well preserved (Pl. XVI, fig. 8). In this they bend abruptly backward on reaching the spiral band before crossing it.

One of my specimens from the chert agrees closely with that figured and described by Hall as *Murchisonia desiderata* var. except in the character of the upper part of the spire, which has the volutions distinctly rotund instead of angular. Spire gradually and regularly tapering with the volutions; striae indistinct; revolving band well marked only in the lower four volutions; those in the upper part of the spire are distinctly rotund. Apparently considerable variation obtains within the limits of this species. Good specimens are very rare.

Formation and locality.

Jeffersonville limestone; Burnsville and Falls of the Ohio.

Naticopsis sp.

Pl XVI, fig. 10.

Shell small, form as indicated by figure; spire low; volutions three or four, the last very large, and regularly rounded. Surface apparently smooth; suture well defined. Aperture unknown. This shell is less globose and more depressed than most of the forms referred to *Naticopsis* and is placed provisionally in this genus.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls.

Naticopsis levis Meek.

N. levis Meek, Pal. Ohio, Vol. I, 1873, p. 215, Pl. 19, figs. 4a, b.

Meek's description.—"Shell apparently attaining a medium size; subovate in general form at maturity, but proportionally shorter in the young; spire moderately prominent; volutions four to four and a half, convex, increasing rather rapidly in size; last one large, or forming near nine-tenths of the entire bulk of the shell, rounded on the sides, and a little extended below; suture well defined; aperture ovate, being regularly rounded below and more or less angular above; col-

umella arcuate and distinctly flattened, or a little concave below the non-perforate umbilical region, above which the inner lip is thickened. Surface only showing obscure lines of growth.

"Length of the largest specimen seen, 0.60 inch; breadth, 0.48 inch; height of aperture, 0.38 inch; breadth of aperture, 0.27 inch."

I have not seen this species, but it is recorded in Hall's list of species from the Falls of the Ohio, 24th Rep. N. Y. State Mus. Nat. Hist., p. 200.

Formation and locality.

Jeffersonville limestone(?); Falls of the Ohio.

Straporollus cyclostomus (Hall).

Pl. XXI, fig. 9.

Euomphalus cyclostomus Hall, Geol. Surv. Iowa, Vol. I, Pt. II, 1858, p. 516.

This species is listed in the State Museum catalogue (16th Ann. Rep., p. 409). The specimen there referred to, however, is a cast which belongs to another species. *S. cyclostomus* has not yet been recognized in Indiana. The specimen of this species which is here figured is from Lime Creek, Iowa.

Pleuronotus decewi (Billings).

Euomphalus decewi Meek, Pal. Ohio, Vol. I, 1873, p. 220, Pl. 19, figs. 3a, b; Pl. 20, fig. 1.

Euomphalus decewi Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 55, Pl. 15, figs. 1-8.

Meek's description.—"Shell attaining a large size, discoid in form, the upper side being moderately concave or nearly or quite flat, and the lower broadly and deeply concave; periphery flattened convex, and nearly vertical to the plane of the shell, or somewhat oblique. Volutions about three, irregularly subquadrangular, increasing regularly and gradually in size from the apex, and coiled more or less nearly (but never exactly) in the same plane, obtusely angular around the upper outer side, and thence flattened, with a more or less inward slope above, to the inner side; lower side of volutions prominent and obtusely angular at its connection with the periphery, from which point it slopes strongly inward, usually with a concave face, into the large umbilicus; aperture like the section of the volutions, irregularly quadrangular, the inner side being much narrower, and the oblique lower side wider, than any of the others. Surface ornamented by distinct lines of growth, and sometimes, on the upper and outer sides of the volutions, by little regular ridges, both of which curve

strongly backward to the angle formed at the meeting of the upper and outer sides, where they make a short backward arch in crossing a slightly concave, undefined band, somewhat like that seen in *Pleurotomaria;* thus indicating a wide, deep notch in the lip at the termination of the upper angle of the volutions. A similar but less strongly defined backward curve of these markings also occurs on the outer surface of the whorls, at the lower angle. Greatest transverse diameter of a large specimen, about 4.30 inches; height of same near the aperture, 1.66 inches."

Internal casts of this species are not uncommon. They may be recognized by the angular character of the volutions, a transverse section of the outer volution being subquadrilateral or triangular. I have seen no specimens preserving the outer surface of the shell.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls, Jefferson County and Falls of the Ohio.

Polyphemopsis louisvillae Hall and Whitf.

P. louisvillae Hall and Whitfield, 24th Rep. N. Y., State Mus. Nat. Hist., 1870, p. 193.

P. louisvillae Nettleroth, Ky. Foss. Shells, 1889, p. 180, Pl. 20, figs. 16-19.

Hall and Whitfield's original description.—"Shell small, ventricose, consisting of about six rapidly tapering volutions, the last of which comprises about two-thirds the entire length of the shell. Aperture large ovate, widest below the middle, and pointed at the upper angle; a little more than half as long as the shell. Columella slight; suture scarcely impressed. Surface smooth."

The specimen here figured is apparently a young individual of this species.

This is a rather rare shell.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Burnsville, Falls of the Ohio.

Turbo shumardi DeVerneuil.

Pl. XXII, fig. 1.

T. shumardi Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 135, Pl. 29, figs. 1-4.

Hall's description.—"Shell gibbous, subglobose. Spire moderately elevated, apex minute; volutions about five or six, gradually enlarging in the earlier stages of growth, and the last one becoming ex-

tremely ventricose, with a broadly expanded aperture; the earlier volutions are smooth and regularly rounded upon the exposed surfaces, gradually becoming nodose and flattened or somewhat concave upon the upper side, the nodes increasing in size and strength with the increase of the volutions. Suture close in the earlier volutions, and becoming somewhat canaliculate in the later ones. Lower side of the outer volution very convex even in the umbilical region, and much extended in the direction of the columella. Aperture broadly rounded or somewhat obscurely pentahedral; columellar lip obtuse, thickened, having a distinct, broad opercular groove; callus covering the umbilicus and spreading outwardly; external margin of the aperture thin. Surface marked by fine comparatively even striae of growth, which are often crowded in fascicles, and in old shells are somewhat imbricated at irregular intervals. Periphery of the outer volution with a strongly elevated obtusely angular carina, which is continued from the suture line at the inner posterior angle of the aperture. The outer one or two of the volutions (depending on the size of the shell) marked by strong curving nodes, which, commencing just below the suture, are nearly vertical for a short distance, and thence curving forward are finally directed toward the aperture, and gradually become merged in the general surface. The striae originating at the suture, are first directed backward, and thence gently curving over the nodes, become nearly vertical and thus continue to near the peripheral carina, where they are turned a little backward and, passing this elevation, they are directed with a slight curve toward the columella."

The above description is based upon specimens from the Falls of the Ohio. This species occurs also in the northern Indiana Devonian. A specimen from the latter region shows the strong folds or nodes which extend entirely across the upper side of the outer volution from the suture and are directed backward. This is a rare fossil.

Formation and locality.

Little Rock Creek, Cass County, and Falls of the Ohio.

PLEUROTOMARIA.

A. Surface cancellated by regular revolving striae.
  b. Shell large with rotund form and convex volutions. *P. luçina* and *var. perfasciata.*

AA. Surface without revolving striae.
  c. Peripheral band divided by a central carina. *P. procteri.*
  cc. Peripheral band without a central carina.
    d. Shell with two carinae below the peripheral band. *P. arbella.*
    dd. Shell without two carinae below the peripheral band. *P. sulcomarginata.*

Pleurotomaria sulcomarginata Conrad.

Pl. XX, figs. 9, 10.

P. sulcomarginata Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 69, Pl. 19, figs. 8-17.

Hall's description.—"Shell depressed trochiform; spire moderately elevated; apex minute. Volutions four or five, very depressed convex on the upper side, gradually enlarging to the last one, which becomes somewhat ventricose. Aperture subquadrate, somewhat wider than high, the columella much extended below.

"Surface marked by two distinct narrow revolving carinae on each volution, one just below the suture, and the other near the periphery, with finer intermediate striae which are rarely visible; the entire surface marked by strong regular and even concentric striae which crenulate the revolving carinae, and, passing over the lower one, bend backward to the concave peripheral band. Suture sometimes sharply canaliculate.

"In entire specimens the apex is very minute, and, when the outer carination is crenulated by the strong concentric striae, the shell has a coronate aspect. This carination, however, is often obsolete on the outer volution, and more rarely on the next above, and the striae then continue uninterruptedly bending backward to the peripheral band, and continuing on the lower side often very nearly of the same strength as above. There is frequently a narrow depressed band just below the peripheral band on the last volution, causing a slight deflection of the striae. The striae are usually finer, and sometimes become nearly obsolete below the outer carination, and more rarely on other parts of the shell, especially near the aperture."

This is a rather common species at some localities in southern Indiana.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Lexington, Charlestown, Lancaster and Falls of the Ohio.

Pleurotomaria lucina Hall.

P. lucina Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 67, Pl. 18, figs. 1-11.

Hall's description.—"Shell subglobose, or obliquely ovoid-conical. Spire moderately elevated; apex minute. Volutions about four, gradually expanding to the last one, which becomes very regularly ventri-

cose, with the aperture expanded and nearly rounded, extended over the lower side, with a shallow notch on the anterior margin; upper side of the volutions very symmetrically convex; suture neatly defined, slightly canaliculate; lower side of the body volution convex in the middle and abruptly curving into the umbilical depression. Surface beautifully cancellated by concentric and revolving striae, which, in many specimens, are of equal strength. Periphery marked by a moderately wide band, on which the striae are turned abruptly backward. This band is limited by stronger striae or narrow ridges on each side, sometimes with one or two slender revolving striae within the limits of the band, marking a narrow space which is often crenulated by the concentric striae.

"This species is well marked by its symmetrically rotund form with moderate elevation of the spire, and the regular convexity of the volutions, even in casts of the interior when not compressed. There is some variety in the surface markings of the specimens apparently belonging to this species. The concentric striae are sometimes much coarser than the revolving ones; and finer striae are implanted between the stronger ones, and do not reach the suture line. In old individuals the revolving band is sometimes nearly a quarter of an inch in width. A very symmetrical specimen has a diameter of a little more than two inches, and is nearly an inch and three-fourths in height. Another specimen, which has suffered some compression, has a breadth of about three inches, with nearly the same height of spire."

The State Museum contains one specimen of this species, the only one I have seen.

Formation and locality.

Sellersburg beds (?) and Jeffersonville limestone; Falls of the Ohio and Charlestown.

Pleurotomaria lucina var. *perfasciata* Hall.

P. lucina var. perfasciata Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 83, Pl. 21, figs. 19, 20.

This variety differs from P. lucina according to Hall in having somewhat stronger striae, and in the character of the concentric and revolving striae on the last volution; the latter where crossing the transverse striae produce a nodose surface, "giving the shell a coarse rude aspect quite unlike the ordinary forms of this species."

Formation and locality.

Nettleroth reports this variety from the "Corniferous limestone;" Falls of the Ohio.

Pleurotomaria arbella Nettleroth.

P. arbella Nett., Ky. Foss. Shells, 1889, p. 171, Pl. 26, fig. 12.

Nettleroth's original description.—"Shell rather large, turbinate, spire elevated; apex minute, aperture subquadrate, apparently somewhat wider than high. Volutions five or six, prominently convex, rapidly enlarging, last one or body whorl very ventricose. Shell wider than high. Surface marked by three revolving carinae, of which one is above and the other two below the peripheral band; the band itself is flat and narrow, and not limited by elevated carinae; the upper part of the volution at least in the two last ones, is gently sloping from suture to the first or upper carinae; from this it curves to the spiral band, forming a moderately deep rounded furrow.

"The interspaces between band and second carina, and between this and the third or last carination, are also rounded depressions, of which only the one next to the band is of about equal depth with the furrow in the upper half; the second depression in the lower half is shallow. In consequence of the great convexity of the volutions the suture is deep. The character of the transverse striae is only indicated but not fully known."

This species is known only from the type in the Nettleroth collection.

Formation and locality.

"Corniferous limestone;" Clark County.

Pleurotomaria procteri Nettleroth.

P. procteri Nett., Ky. Foss. Shells, 1889, p. 173, Pl. 21, figs. 9, 10, 13.

Nettleroth's original description.—"Shell trochiform; height exceeding width about one-fourth or more. Volutions from five to six, somewhat rapidly increasing in size, the last one ventricose; there is only one carina above and one below the peripheral band; the carina above the band gives to the upper portion of the volution a subangular appearance, while the lower part is regularly rounded. The peripheral band is divided by a somewhat finer central carina, which is crossed rectangularly by strong striae, which only extend from margin to margin of the peripheral band with interspaces of about four times their own size. These rectangular striae are entirely separated from the striae of the upper or lower half of the volution; they give the dividing carina a beautifully crenulated appearance. On both sides of the peripheral band the surface is ornamented by

strong transverse striae; in the upper half they start from the suture, and run in an almost straight line, with a backward deflection of about ten degrees, to the first carina, from which they curve slightly backward to the upper marginal carina of the peripheral band. This system of striae, interrupted by the band, continues at the lower marginal carina of the latter, from where the striae extend in slightly curved or nearly straight lines with a forward deflection, either to the sutures of the upper volutions, or to the lower carina of the body whorl. From this lower carina, which forms the suture line of the upper whorls, and which is therefore only visible on the last volution, the striae curve gently to the umbilicus and to the columellar lip; but a great number of them die out or become extinguished at different distances from the lower carina. All the volutions are, in their transverse sections, extremely convex, which gives them very deep sutures, and separates them from each other in a very decided manner. The aperture of this shell is not known, inasmuch as in all the specimens in my collection the outer lip is missing."

Formation and locality.

Nettleroth reports this species from the "Corniferous limestone of Clark County."

TROCHONEMA.

A. **Surface marked by nodes.** *T. yandellanum.*

AA. **Surface not marked by nodes.**

- b. **Body volution bicarinate.**
  - c. **The lower carina of the whorls of the spire separated from the suture by an interspace.** *T. emacerata.*
  - cc. **The lower carina of the whorl of the spire coincident with the suture.** *T. rectilatera.*
- bb. **Body volution with three or more carinae.** *T. meekanum.*

Trochonema meekanum (Meek).

Pl. XVI, fig. 9.

Trochonema tricarinatum Meek, Pal. Ohio, Vol. I, 1873, p. 218, Pl. 19, figs. 4a, b.

Meek's description.—"Shell turbinate, thin, a little wider than high; spire depressed. Volutions about five, strongly shouldered, or nearly rectangular above, the upper surface being flat or a little concave, and extended out almost horizontally to the rectangular and carinate shoulder; below this the outer side is nearly vertically flattened to a second carina, passing on around near the middle of the body whorl, exactly coincident with the suture between that and the

succeeding turn, so as not to be exposed on the spire; below this second carina the under side of the body volution is flattened with a strong inward slope, to a third well defined carina, passing around the middle of the under side, and forming the margin of the umbilicus. Aperture oval-subpentagonal, being a little higher than wide, and somewhat angular above at the connection of its outer lip with the return of the spire, and at the termination of each of the three revolving carina, as well as very obscurely so, a little below the middle of the inner side; under lip thin below its connection with the carina, passing around the umbilicus, at which point it is very slightly thickened, while above this it seems to be nearly or quite obsolete. Umbilicus rather wide, but shallow, or very rapidly contracting within.

"Suture well defined without being in the slightest degree furrowed. Surface only showing very fine lines of growth, which, on the upper flattened space of the volutions, pass obliquely outward and backward, with a very slight curve from the suture to the upper angle or shoulder, below which they pass nearly straight down the outer flattened area to the second carina, which is as far as they can be traced in the specimen studied.

"Height, 0.81 inch; breadth, 0.90 inch; height of aperture, 0.54 inch; breadth of aperture, 0.46 inch."

The specimen here figured is a guttapercha cast. It differs from Meek's description in some respects, the height slightly exceeding the width, and the surface striae being stronger than his figure would indicate. The specimen also shows below the carina limiting the lower side of the flat peripheral band of the body whorl two other revolving carina and a third indistinct one. It seems best, however, in the absence of material for studying the variation of the species, to regard this as a variation of Meek's species.

Formation and locality.

Jeffersonville limestone; Newbern.

Trochonema yandellana Hall and Whitf.

T. yandellana Hall & Whitfield, 24th Rep. N. Y. State Mus. Nat. Hist., 1872, p. 194.

T. yandellana Hall & Whitfield, 27th Rep. N. Y., State Mus. Nat. Hist., 1875, Pl. 13, fig. 3.

Hall and Whitfield's original description.—"Shell turbinate volutions about five (three of which are preserved in the specimen), rapidly increasing, carinated; the last volution becoming ventricose

and marked by seven revolving carinae, including the one bordering the somewhat channeled suture; four of the carinae are distinctly marked by thin lanceolate nodes, which become more prominent with the increased growth of the shell, while the other three—one bordering the suture and two on the lower middle portion of the volution—are destitute of nodes (in the specimen described), but may possibly assume this character in more advanced stages of growth. The carinae are situated one at the suture and one bordering the moderately large umbilicus, with five on the body of the volution, of which two are above the middle and three below; the spaces separating those bordering the suture and umbilicus from those on the body of the volution, are considerably wider than the spaces between the intermediate carinae. Aperture rounded, slight, modified by the carinae. Surface marked by fine transverse striae of growth, which turn backward as they cross the volution, to the umbilicus."

I have not seen this species.

Formation and locality.

"Cherty layers of the Corniferous limestone;" Falls of the Ohio.

Trochonema emacerata Hall and Whitf.

T. emacerata Hall & Whitfield, 24th Rep. N. Y. State Mus. Nat. Hist., 1872, p. 193.

T. emacerata H. & W., 27th Rep. N. Y. State Mus. Nat. Hist., 1875, Pl. 13, fig. 11.

Hall and Whitfield's original description.—"Shell turbinate, consisting of four or five volutions, the upper ones moderately convex and bicarinate; the suture line commences a little below the second carina. The last volution is very ventricose, with a rounded aperture; umbilicus small.

"Surface marked apparently only by lines of growth.

"This species differs from *T. tricarinata* Meek, in the more elevated spire, the sloping side of the volutions between the suture and the first carina, and in having two carinae with an interspace equal to that above and below, while there is no evidence of a carina bordering the narrow umbilicus."

This species is rare.

Formation and locality.

"In limestone above the 'Hydraulic beds';" Sellersburg beds; Louisville.

Trochonema rectilatera Hall and Whitfield.

T. rectilatera H. & W., 24th Rep. N. Y. State Mus. Nat. Hist., 1872, p. 193.

T. rectilatera H. & W., 27th Rep. N. Y. State Mus. Nat. Hist., 1875, Pl. 13, figs. 4-5.

Hall and Whitfield's original description.—"Shell turbinate, breadth and height almost equal; volutions about five, carinated above with straight nearly vertical sides; outer one ventricose with two distinct carinae having a wide, vertical, slightly concave space between, which occupies more than one-third of the height of the volution. Upper side of the volution convex for half the distance to the carina, and below this they are concave, giving the form of an ogee.

"In another specimen, apparently identical, the upper side of the volutions are slightly concave and regularly sloping downward from the suture to the carina. Lower side of the volution not carinate; umbilicus small, or closed with a callosity.

"Surface marked by fine striae of growth, which are turned backward from the suture, and are vertical on the sides of the volution, and on the lower side curve backward to the umbilical area."

Formation and locality.

"Upper limestones" (Sellersburg beds?); Falls of the Ohio.

Cyclonema crenulata Meek.

Pl. XXI, figs. 10, 11.

C. crenulata Meek, Pal. Ohio, Vol. I, 1873, p. 213, Pl. 19, figs. 2a, b, c, d.

Meek's description.—"Shell turbinate, subtrochiform, thin; spire depressed conical, volutions four, increasing rather rapidly in size, those of the spire convex, but not rounded; last one not large, convex on the upper slope of the periphery, which is rather narrowly rounded; suture well defined between the upper volutions, and somewhat canaliculate further down; aperture ovate. Surface ornamented by sharply elevated revolving lines or small ridges, which are beautifully and intimately crenulated by the crossing of the very fine, very oblique lines of growth. Of these revolving lines from sixteen to eighteen may be counted on the body volution and sixteen on the next above, while those farther up appear to be quite smooth.

"Length, 0.34 inch; breadth, 0.32 inch."

I have several specimens of this species, all from the northern Indiana Devonian. The revolving striae are not noticeable on the third volution, as indicated by one of the figures.

Formation and locality.
Jeffersonville limestone; Bunker Hill and Pipe Creek Falls.

Cyclonema cancellata.

C. cancellata Hall, 27th Ann. Rep., N. Y. State Museum Nat. Hist., 1875, Pl. 13, figs. 6-7.

This species was figured by Hall, but not described. I have not been able to recognize it in my collections.

Formation and locality.
Jeffersonville limestone(?); Falls of the Ohio.

Aclisina barnetti n. sp.

Pl. XXIII, fig. 3.

Shell elongate conical; volutions seven or eight in mature specimens, compressed convex, the lower third descending to the suture with a distinctly convex outline, while the upper portion is flat; volutions regularly increasing from the apex. Suture well defined and rather deeply impressed. The volutions of the spire have the surface marked by from six to eight strong revolving lines; the body volution has about twice this number, half of which are on the lower side of the volution.

The smallest specimen observed has a length of 7/50 of an inch and only five volutions. In four specimens examined the length is about one and a half times the width.

Formation and locality.
Jeffersonville limestone; Pipe Creek Falls and Bunker Hill.

Aclisina barnetti var. *elongata* n. var.

Pl. XXIII, fig. 4.

The elongate form of one specimen seems to justify its separation from the others as a well marked variety. Its length equals the width.

Formation and locality.
Jeffersonville limestone; Keesport, Cass County.

EUOMPHALUS.

A. Surface marked by revolving plications. ***E. sampsoni.***
AA. Surface not marked by revolving plications.
b. Apex elevated above the plane of the outer volution. ***E. (Straparollus) exiguus* n. sp.**
bb. Apex not elevated above the plane of the outer volution. ***E. planodiscus.***

Euomphalus planodiscus Hall.

E. planodiscus Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 57, Pl. 16, figs. 1-4.

An imperfect specimen in the collection is referred with some doubt to this species. The apex of the spire is depressed below the plane of the outer volution; volutions four; periphery rounded, upper surface of outer volution slightly depressed; volutions slender, barely contiguous. Surface markings not well preserved. Diameter one and one-tenth inches.

Formation and locality.
Jeffersonville limestone; Bunker Hill.

Euomphalus (Straparollus) exiguus n. sp.

Pl. XXI, fig. 8.

Shell small, discoid, spire depressed. Volutions about four, rounded contiguous except the first and second, which are sometimes separated for a short distance by a slight space. Gradually enlarging from the apex, which is elevated a little above the plane of the outer volution. Umbilicus broad. Surface concentrically striated by very fine striae.

Formation and locality.
Jeffersonville limestone; Hope and Newbern.

Euomphalus sampsoni Nettleroth.

S. sampsoni Nett., Ky. Foss. Shells, 1889, p. 182, Pl. 21, figs. 3-4.

Nettleroth's original description.—"Shell discoid, but generally by apical decollation receiving the shape of a horn; both sides considerably concave; the periphery broadly convex. Number of volutions unknown, probably only two. The outer volution rapidly increasing in size; its cross section near the apex circular, near the aperture oval. The surface is ornamented by from twenty-five to thirty strong simple plications, each of which extends over the whole length of the outer or last volution, and may probably reach back to the apex.

These plications increase in strength from apex to the aperture; their interspaces are also gradually widening in their course toward the front; they are of unequal width; some are of four times and others of double the size of the adjacent ribs. My specimen's being internal casts completely silicified into hornstone, no other surface markings are retained.

"Form and size of the aperture unknown."

This species is known only by the types.

Formation and locality.

Sellersburg beds; Watson.

Capulus cassensis n. sp.

Pl. XVI, fig. 11.

Shell small, subconical, nearly erect, the apex inclined slightly backwards; aperture ovate, its length and the height of the shell are in the ratio of three to four. The surface is marked by very fine concentric striae and by distinct regular lamellae which lap upwards, the exposed margin of each being on the upper side instead of the lower, as in ordinary lamellae. The lamellae and striae bend very slightly upward in crossing the front side of the shell and arch rather abruptly downwards in crossing the posterior side. There appear to be faint traces of radiating striae over a part of the surface.

The peculiar regular lamellae seem to distinguish the shell from any other species. The specimen figured measures in height 21/50 of an inch; the diameters of the aperture are 15/50 and 12/50 of an inch respectively. Two other specimens measure respectively 11/50 and 13/50 of an inch in height.

Only three specimens have been observed.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls, Cass County.

PLATYCERAS.

A. Shell with spines.
- **b. Spines in a single line along the dorsum.** *P. blatchleyi.*
- **bb. Spines not confined to the dorsum.**
  - **c. Shell large.**
    - **d. Shell elongate with loosely coiled spire.** *P. milleri.*
    - **dd. Shell not elongate without loosely coiled spire.**
      - **d[1]. Form erect.** ***P. dumosum* var. *pileum.***
      - **dd[1]. Form usually depressed.**

e. Having few spines.

f. Body volutions greatly expanded. *P. fornicatum.*

ff. Body volution not greatly expanded. *P. dumosum* var. *rarispinum.*

ee. Having numerous spines.

g. Shell very large, greatly depressed, expanding rapidly. Spines very numerous. *P. multispinosum.*

gg. Shell of moderate size, not greatly depressed, with from 15 to 100 spines. *P. dumosum.*

cc. Shell small or of medium size.

h. Posterior margin of peristome contiguous to the preceding volution. *P. rictum* var. *spinosa.*

hh. Posterior margin of peristome distant from preceding volution. *P. echinatum.*

AA. Shell without spines.

i. Dorsum serrated. *P. indianensis.*

ii. Dorsum not serrated.

j. Body volution entirely straight, shell nearly perfectly conical. *P. conicum.*

jj. Body volution not entirely straight, shell not perfectly conical.

k. Dorsum sharply angular or with a carina. *P. carinatum.*

kk. Dorsum without a carina, not sharply angular.

l. Body volution greatly compressed laterally.

m. Apex apparently incurved. *P. fluctuosum.*

mm. Apex closely enrolled.

n. Peristome strongly serrated *P. serratum.*

nn. Peristome not serrated. *P. arctiostoma.*

ll. Body volution not greatly depressed laterally.

o. Shell above the body whorl abruptly contracted, apical whorl very slender. *P. attenuatum.*

oo. Shell not abruptly contracted above the body whorl, apical whorl not very slender.

p. Shell bilaterally symmetrical or nearly so. *P. symmetricum.*

pp. Shell bilaterally symmetrical.

q. Body whorl very ventricose or aperture greatly expanded.

r. Body volution generally contiguous to preceding volution.

s. Surface of body whorl with two or three rounded plications. *P. bucculentum.*

ss. Surface of body whorl usually without plications. *P. ventricosum.*

rr. Body volution not contiguous to preceding volution.
t. Body volution with an oblique angular ridge on the left side. *P. rictum.*
tt. Body volution with several strong longitudinal folds. *P. crassum.*
qq. Body whorl not very ventricose, aperture not greatly expanded.
u. Peristome deeply sinuous. *P. quinquisinuatum.*
uu. Peristome deeply sinuous.
v. Shell arcuate from the base, usually with folds or plications on the right. *P. thetis.*
vv. Shell erect and subarcuate, usually without folds or plications on the right side. *P. erectum.*

Platycerus conicum Hall.

Pl. XVIII, figs. 2, 2a, 2b.

P. (Orthonychia) conicum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 3, Pl. 1, figs. 13-23.

Hall's description.—"Shell erect, conical, the minute apex closely incurved. Body volution entirely straight, with broad undefined longitudinal ridges and depressions, which become more distinct toward the aperture; height of the shell a little greater than the width of the aperture, which is a little longer than wide. Surface marked by concentric undulating striae which become sublamellose toward the aperture and are sometimes closely crowded and wrinkled with numerous knots and nodes. Peristome deeply sinuous; the width from the anterior to the posterior side a little greater than the transverse diameter. The length of the shell is one inch and a half or more, with the aperture a little less."

This is a common species in both northern and southern Indiana. The figures illustrate the principal types of this shell as it is found in the Indiana Devonian.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Pipe Creek Falls, Little Rock Creek, Cass County, Charlestown and Falls of the Ohio.

Platyceras carinatum Hall.

Pl. XVIII, figs 5, 6, 7.

P. carinatum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 5, Pl. 2, figs. 12-29.

Hall's description.—"Shell obliquely subconical or subpyramidal; the nucleus or apex minute, and making from one to one and a half volutions which are vertically compressed, and below which the body

volution is abruptly expanded; the dorsum angular or marked by an angular carina which often becomes double in old shells, or is rounded on the summit. This angularity or carina indicates, by direction of the striae, the existence of a sinus in the peristome from an early period of growth; and sometimes there may have been two of such sinuosities close together, giving the double carina. There is usually a depression along one or both sides of the carina, with longitudinal folds (obscure plications) on one or both sides, which become more strongly developed toward the aperture, and are very conspicuous in old shells; the right side is more expanded than the left, and in some well preserved specimens is nearly twice as wide. Aperture very oblique, rhomboidal or subtriangular, and the peristome sinuous.

"Surface marked by fine, closely arranged, undulating striae of growth, which are not lamellose."

The figures illustrate the two principal types of shells which are referred to this species, those with a carina and those with an angular dorsum.

This is not a very common species.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Pipe Creek Falls and Charlestown.

Platyceras dumosum Conrad.

Pl. XVII, fig 1.

P. dumosum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 14, Pl. 5, figs. 11-16; Pl. 6, fig. 1.

Hall's description.—"Shell subovoid, arcuate, extremely ventricose when full grown; the length from the apex to the anterior margin of the aperture greater than the height. Apex minute, closely enrolled for a single volution or more, when the body volution becomes free and rapidly expanded, spreading more upon the right side, which is sometimes depressed-convex, while the left side is more abruptly rounded. The aperture is subrhomboid-ovate, with the peristome making a sinus on the left side, the posterior margin widely separated from the preceding volution.

"Surface marked by strong concentric striae which are interrupted and irregular from the numerous nodes projecting from the shell, and extended into long tubular spines."

This is not a common species.

Formation and locality.

Sellersburg beds; Falls of the Ohio and Charlestown.

Platyceras dumosum var. *pileum* n. var.

Pl. XVII, fig. 2.

Shell large, erect, body volution very ventricose, aperture circular, lip not sinuous. Surface marked by strong concentric striae, and thickly covered by tubular spines, somewhat regularly arranged in diagonal rows.

The spines are very much smaller and more numerous than in averge specimens of *P. dumosum;* in this respect it resembles *P. multispinosum,* but it is much more erect than either of these species and seems to be a well marked variety.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Platyceras multispinosum Meek.

Pl. XVII, fig. 3.

P. multispinosum Meek, Pal. Ohio, Vol. I, 1873, p. 210, Pl. 20, fig. 7a, b.

This species differs from *P. dumosum* according to Meek "not only in its much larger size, more oblique, depressed, and more rapidly expanding form, but in having much more numerous spines."

I have seen but one specimen of this species, which is here figured.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Platyceras dumosum var. *rarispinum* Hall.

Pl. XVII, fig. 4.

P. dumosum var. rarispinum Hall, Pal. N. Y., Vol. V, Pt. II, 1873, p. 16, Pl. 5, figs. 5-7, 10.

This variety is characterized by having a smaller size, less ventricose shell and fewer spines than *P. dumosum.*

Mr. Green's collection contains two specimens which I refer to this variety. The largest of these has a height of 1⅖ inches; the diameter of the aperture about equals the height; the aperture is nearly circular in outline and is somewhat sinuous in front. The surface is covered by coarse wrinkled striae and appears to have had only about four or five spines.

Formation and locality.

Sellersburg beds(?); Charlestown and Falls of the Ohio.

Platyceras milleri Nettleroth.

P. milleri Nett., Ky. Foss. Shells, 1889, p. 165, Pl. 25, fig. 1.

One specimen in Mr. Green's collection is referred to this species. The apical volution is broken away. Upper portion of the shell spirally twisted to the left; shell enlarging gradually. Surface marked by fine concentric striae which are crowded into wrinkles on the anterior side; tubular spines are distributed over the surface, but not so abundantly as in the specimen figured by Nettleroth. The greater part of these are confined to the dorsal part. Aperture somewhat compressed laterally.

Formation and locality.

Sellersburg beds; Charlestown.

Platyceras thetis Hall.

Pl. XIX, figs. 1, 1a; XVIII, figs. 8, 8a, 9.

P. thetis Hall, Pal. N. Y., Vol. V, Pt. II, 1879, Pl. 3, figs. 11-16.

Hall's description.—"Shell obliquely arcuate from the base, with the apex incurved, the nucleus making barely more than a single minute volution; gradually expanding from the apex to near the aperture, which is sometimes more abruptly spreading. The back of the body whorl is prominent, and a little flattened on the left side; while the right side from one-third to one-half the length is sometimes marked by two or three longitudinal folds, and often by more numerous, finer plications. Aperture a little oblique, nearly round or subquadrangular, with the peristome sinuous.

"Surface marked by fine, closely arranged lamellose striae, which are abruptly undulated on all parts of the body of the shell."

Two of the specimens here figured represent extreme types of the shell; one is long, slender and gently arcuate; the second is short and abruptly curved; in the latter specimen the apex is incurved in the same plane as the body whorl, and resembles in this respect *P. symmetricum*, but has not the extended body whorl of this species.

The third specimen is referred with considerable doubt to this species. A slight fold marked by the upward arching striae occupies the dorsum and terminates in a well marked sinus in the peristome.

Formation and locality.

Sellersburg beds; Charlestown.

Platyceras sp.

Pl. XIX, fig. 8.

Shell arcuate from the base. Apex closely incurved for about one volution, twisted a little to the right, gradually enlarging to the aperture. Below the apical whorl, which is gently convex, the shell is marked by four strong longitudinal plications, which give the body volution a roughly quadrilateral shape. These longitudinal folds are separated by wide, shallow depressions.

Surface marked by lamellose striae.

I have not been able to identify this shell with any of the described forms. It may be compared with *P. thetis* and may possibly be a variety of that species.

Formation and locality.

Jeffersonville limestone; Charlestown.

Platyceras fornicatum Hall.

P. fornicatum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 11, Pl. 4, figs. 1-5, 7-8, 18-20; Pl. 5, figs. 8, 9, (?).

Hall's description.—"Shell obliquely subhemispherical, or very depressed, obliquely subconical. Apex minute, distinct, spirally enrolled for about one turn and a half, below which it expands, so that in the extent of an inch and a half along the dorsum to the front it has acquired an aperture of about an inch and a half in diameter in both directions. The upper side of the spire for the first volution and the following half is flattened; the angle continuing into the broad expansion of the body whorl, and dying out before reaching the margin, as shown in figs. 1-5. Aperture nearly round or round ovate; peristome scarcely sinuous, except at the posterio-lateral margin.

"Surface marked by fine concentric striae, with a few strong spines upon the body volution."

Hall includes this species in his list* of Devonian fossils from the Falls of the Ohio. I have not seen it.

Platyceras bucculentum Hall.

Pl. XIX, figs. 3, 3a, 3b, 4, 4a.

P. bucculentum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 10, Pl. 3, figs. 7, 26-29.

Hall's description.—"Shell ventricose, obliquely subovoid. Apex extremely attenuate, the spire making one or two closely enrolled

*24th Ann. Rep. N. Y. State Mus. Nat. Hist., 1870 p. 200.

volutions, with a gently enlarging diameter, and below this abruptly expanding and becoming very ventricose in the middle and lower part; spreading more upon the right side than on the left; the shell near the posterior side swells out into a distinct pouch-like projection with two or three rounded folds or semiplications, which give a deeply sinuous outline to the margin. Aperture subovate, and sinuate on the right posterior side. Peristome sinuous, and on the posterior side spreading partially over the preceding volution.

"Surface marked by fine, closely arranged concentric striae which are undulated toward the margin of the aperture, and sometimes over the greater part of the surface, the irregularity having commenced during the earlier stages of growth. In well preserved specimens there are revolving striae or fascicles, rising in little bands of obsolescent striae, giving a waved aspect to the surface."

Some of the specimens which I have referred to this species are greatly depressed, and with their lateral expansion present a subtriangular outline viewed from above. In each of the specimens figured the shell has been more or less broken away about the aperture. Other specimens which preserve this part of the sheil show a strongly sinuous peristome. The "two or three rounded folds" on the posterior side mentioned by Hall are generally wanting in my specimens, but the greatly expanded and ventricose body volution seems to place them with this species. One or two specimens show traces of revolving striae.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Charlestown and Kent.

Platyceras symmetricum Hall.

P. symmetricum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 9, Pl. 3, figs. 17-25.

Hall's description.—"Shell elongate, subovoid, arcuate, incurved nearly in the same plane; nucleus minute, the spire making about one volution or one and a half, when the body whorl becomes free and rapidly, or somewhat abruptly, expanded; spreading about equally on the two sides of the dorsum, which is more prominent and sometimes marked by a ridge. Aperture oblique, subquadrate or rhomboidal, margin of the peristome sinuate, and on the posterior side distant from the spire.

"Surface marked by concentric undulating striae, and longitudinally by obscure interrupted ridges, which on some parts of the older

shells become regular and uniform, with a narrow groove between."

The specimens which I have referred to this species show very slight traces of longitudinal ridges and have the surface nearly smooth except for concentric striae. They are characterized by their bilateral symmetry, having the apex in nearly the same vertical plane as the dorsum.

Formation and locality.

Sellersburg beds; Charlestown.

Platyceras indianensis Miller and Gurley.

Pl. XIX, figs 9, 9a.

P. indianensis M. & G., Bull. Ill. State Mus. Nat. Hist. No. 12, 1897, p. 48, Pl. 4, figs. 7-10.

Miller and Gurley's original description.—"Species rather large. The back of the body whorl from the apex to the aperture is sharply angular and strongly serrated. Toward the apex the shell is laterally compressed, but it expands laterally toward the aperture. The apex is sharply pointed. The shell makes about one volution, in nearly the same plane, when the apex comes in contact with the rapidly spreading body whorl. The aperture is compressed subelliptical, in outline, in the specimen illustrated by figure 9, with a moderately deep sinus at the angular back of the body whorl. And the shell substance is thin, which indicates, probably, a young shell, or, it may be, the apical end of a mature specimen.

"Figure 10 represents a mature specimen. It is much extended upon the back of the body whorl and the shell gradually becomes thicker, but the aperture below the beak remains in the same position that it is in the specimen shown in figure 8. The aperture increases its length, and by reason of the lateral expansion of the shell with the growth, it retains a compressed subelliptical outline, but acquires a deep, sharply angular sinus at the back of the shell.

"The surface is marked by concentric undulating striae, that become more and more pronounced toward the aperture. They are not shown in the illustrations."

The specimen here figured is referred to this species with some doubt.

The angular back is surmounted by a small, sharp carina which appears to be somewhat serrated. The removal of the specimen from the limestone has left this feature indistinct. The figures fail to show the somewhat distinct serration which is noticeable near the aperture. This shell has certainly not been as strongly serrated along

the dorsum as the typical specimens of *P. indianensis* and is regarded as a variety of that species.

P. indianensis is not uncommon in southern Indiana. Mr. Green's collections from Charlestown contain five or six typical specimens.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Little Rock Creek, Cass County, and Charlestown.

Platyceras (Orthonychia) attenuatum Hall.

Pl. XIX, fig. 6.

P. (Orthonychia) attenuatum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 6, Pl. 3, figs. 1-6.

Hall's description.—"Shell elongate-ovate or conically subovate with a slender apex, the nucleus making about one volution or one and a half, below which the body whorl becomes rather abruptly inflated, and thence gradually expands to the aperture, which is very oblique—the anterior side of the peristome being much more extended.

"Surface marked by crowded, undulating concentric striae and longitudinal, irregular and undefined folds, which vary greatly in different specimens; the latter becoming more distinctly marked as plications near the aperture. Peristome sinuous, with numerous indentations corresponding to the folds upon the surface."

The specimen here figured does not preserve any of the original surface markings. The small circular spots shown by the figure indicate a peculiar structure developed during the silicification of the specimen. Two or three faint undefined plications are noticeable on the sides. A rather deep sinus marks the posterior side of the peristome.

Formation and locality.

Sellersburg beds; Charlestown.

Platyceras erectum Hall?

Pl. XIX, fig. 7.

P. erectum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 5, Pl. 11, figs. 4-11.

Shell obliquely arcuate, apex minute, closely enrolled for one volution, beyond which the shell rapidly expands to the middle of the body volution, where it attains its maximum diameter. Surface

marked by concentric striae which are somewhat lamellose near the aperture. A faintly defined fold marks the dorsum.

One specimen is referred to this species with some doubt.

Formation and locality.

Sellersburg beds; Charlestown.

Platyceras rictum Hall.

P. rictum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 13, Pl. 4, figs. 6, 12-17.

P. rictum Nettleroth, Ky. Foss. Shells, 1889, p. 166.

Nettleroth records this species. I have not seen any specimens that could be referred with certainty to it.

Formation and locality.

"Corniferous limestone" (Jeffersonville limestone?); Clark County.

Platyceras rictum var. *spinosa* n. var.

Pl. XVII. figs. 5, 5a, 5b 5c.

Shell much depressed, strongly arcuate; apex minute; spire closely and obliquely enrolled about one and a half turns, when it abruptly expands, forming the large ventricose, closely enrolled body volution. Shell either sharply or gently rounded along the dorsal line of the body volution, with an oblique form inclining to the left. Peristome reflected in front, almost in contact with the spire. Surface marked by undulating concentric striae and irregularly arranged tubular spines; the spines vary in number from three or four up to fifteen or twenty. This form differs from *P. rictum* in its less angular or rounded dorsum, and in having the surface marked by spines. Mr. Green's collection contains several specimens of this shell; all of them have the aperture partially broken away so that they do not permit of a perfectly satisfactory comparison with *P. rictum.*

Formation and locality.

Sellersburg beds; Charlestown.

Platyceras ammon Hall.

P. ammon Hall. Pal. N. Y., Vol. V, Pt. II, 1879, p. 20, Pl. 8, figs. 7-10.

This species is listed in the State Museum catalogue of Fossils (16th Ann. Rep. Ind. Dept. Geol. and Nat. Hist., p. 409). The specimen there referred to is too poorly preserved to admit of a satisfactory identification. I have not recognized this species in my collection.

Platyceras crassum Hall?

P. crassum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 18, Pl. 7, figs. 6-10.

I have seen no specimens that can be certainly referred to this species. A few specimens which are not now accessible, were doubtfully referred to this species in a previous paper.*

Platyceras compressum Nettleroth.

P. compressum Nettleroth, Ky. Foss. Shells, 1889, p. 162, Pl. 25, figs. 8-10.

Nettleroth's original description.—"Shell of medium size or below it; very compressed in a lateral direction. Apex closely enrolled for one and a half volutions, which increase in size very gently; after this the body whorl, measuring a little more than a half volution, expands rapidly in the post-anterior direction, while its lateral extension remains almost the same throughout the whole length of the body volution. The right side of the shell is moderately convex in the apical half, but becomes concave in the lower half, the center line of the concavity running at right angles to the peristome. The left side is throughout concave, but the center line of the concavity is parallel to the peristome, or at least nearly so. The aperture is very elongate and narrow, and expands more or less at the posterior end of its right side. The surface is marked by five concentric lamellose striae, which are closely arranged, especially in the lower half, and by somewhat obscure, shallow, radiating plications, only noticed in the lower part.

"A smaller specimen, of about half the size of the one illustrated, does not show any indication of those plications."

Formation and locality.

"Corniferous limestone;" (Jeffersonville limestone?); Falls of the Ohio.

Platyceras compressum var.

Pl. XIX, figs. 2, 2a.

Shell obliquely arcuate, and laterally compressed. Apex minute, closely enrolled for one and a half volutions, which gradually increase in size. The body volution expands rapidly in the anterior and posterior direction, but beyond the apical whorls, which are moderately convex on the sides, the shell develops a wide sinus on

* Bull. Amer. Pal. No. 12, 1899 p. 75.

the right side which deepens gradually toward the aperture; the left side is slightly convex or nearly flat to within a short distance of the aperture, where a shallow sinus is developed corresponding in position to the one on the opposite side. The dorsum is sharply rounded. Aperture contracted anterior to the lateral sinus and expanded at the posterior end. The peristome on the left side near the posterior margin is bent in; but this probably is abnormal. Surface marked by fine concentric somewhat wrinkled striae.

This shell appears to be closely related to *P. compressum* Nettleroth, but does not have the left side concave throughout as in that species; the post-anterior width of the body whorl is proportionally much less in this form than it is in *P. compressum*. The enormous variation to which shells of this genus are subject, however, serves scarcely to justify recognizing a new species in this form without direct comparison with the type of *P. compressum*, so that it is here regarded only as a variety of that species.

Formation and locality.

Sellersburg beds; Charlestown.

Platyceras ventricosum Conrad.

P. ventricosum Meek, Ill. Geol. Rep., Vol. III, 1898, p. 441, Pl. 2, figs. 4a, b.

P. ventricosum Nettleroth, Ky. Foss. Shells, 1889, p. 168, Pl. 25, fig. 10.

This species has been reported from the Indiana Devonian by Nettleroth. I have not seen it.

Formation and locality.

"Corniferous limestone" (Jeffersonville limestone); Clark County.

Platyceras echinatum Hall.

P. echinatum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, Pl. 5, figs. 1-4.

P. echinatum Nettleroth, Ky. Foss. Shells, 1889, p. 164, Pl. 33, fig. 21.

Hall's description.—"Shell small, obliquely subovoid. Apex closely incurved for about one volution or one and a half; the body whorl from one half to one volution is ventricose, rapidly expanding from the first, giving an obliquely conical form. Aperture nearly circular or broad oval; peristome sinuate, the lines of growth and fine striae conforming in direction to the outline of the margin. Remains of revolving striae are sometimes traceable, when the shell is not exfoli-

ated. Besides the concentric and less conspicuous revolving striae, the surface is studded with numerous nodes and small spines, the latter preserved only where the shell has been embedded in the soft shale, and quite separable from the rock; when embedded in limestone, the spines and exterior shell are removed with the matrix."

Nettleroth has figured a specimen of this species from the Falls. I have not seen it.

Formation and locality.

"Corniferous limestone" (Jeffersonville limestone?); Falls of the Ohio.

Platyceras (*Orthonychia*) *fluctuosum* Ulrich.

P. fluctuosum Ulrich, Contrib. Am. Pal. 1886, p. 31, Pl. 3, figs. 6-6b.

Ulrich's original description.—"Shell obliquely conical, laterally compressed, gradually expanding; dorsum straight or arcuate; apex obtusely pointed, apparently not incurved. Surface or apical half of shell with irregular undulations or protuberances; lower half plicated longitudinally, the plications unequal, and crossed by irregular undulating lines of growth. Aperture narrowly ovate, with the margin sinuate, or rather irregularly serrated."

Formation and locality.

"Middle Devonian (Up. Helderberg?); Falls of the Ohio."

Platyceras (?) *arctiostoma* Ulrich.

P. arctiostoma Ulrich, Contrib. Am. Pal., Vol. I, 1886, p. 30, Pl. 3, figs. 7-7b.

Ulrich's original description.—"Shell semirhomboidal, obliquely enrolled, and consisting of about two volutions; apex minute, depressed; outer volution compressed laterally, rapidly increasing in height, but slowly in width, with the sides, which diverge at an angle of 45 degrees, flat at the aperture, and slightly convex near the nucleus whorl; the upper side is longitudinally concave and narrowly rounded toward the depressed apex; the periphery is subangular, and the lower side rather flat and abruptly rounded into the large umbilicus. Aperture oblique, extremely elongate, with the sides subparallel.

"Surface marked by fine, well developed, and somewhat undulating striae of growth. These are crossed by faint revolving lines. Where the external layer of the shell is preserved the surface is polished."

This species is known only by the type specimen.

Formation and locality.

"Lower Devonian" (Jeffersonville limestone); Falls of the Ohio.

Platyceras (Orthonychia) fluctuosum Ulrich.

P. (Orthonychia) fluctuosum Ulrich, Contrib. Am. Pal., Vol. I, p. 31, Pl. 3, figs. 6-6b.

Ulrich's original description.—"Shell obliquely conical, laterally compressed, gradually expanding; dorsum straight or arcuate; apex obtusely pointed, apparently not incurved. Surface of apical half of shell with irregular undulations or protuberances; lower half plicated longitudinally, the plications unequal, and crossed by irregular undulating lines of growth. Aperture narrowly ovate, with the margin sinuate, or rather, irregularly serrated. This shell differs from all the species belonging to the genus or subgenus *Orthonychia* Hall in the compressed form and irregular surface undulations. It may be compared with *P. (O.) perplexum* Hall from the Upper Helderberg of New York."

The only specimens which have been found are in the collections of Mr. Green.

Formation and locality.

"Middle Devonian" (Jeffersonville limestone); Falls of the Ohio.

Platyceras blatchleyi n. sp.

Pl. XVII, fig. 6.

Shell arcuate, depressed; apex minute, closely enrolled for about three-fourths of a volution, when it abruptly widens into the greatly expanded body volution. The shell is compressed along the dorsal line from the apex to the posterior margin, giving it a sharply angular dorsum; the angular dorsum supports seven strong and somewhat compressed spines which are directed backwards. There may have been and probably were two or three other spines, anterior to those shown in the figure, which are not preserved. The right side is rather more expanded than the left. Shell in front descending almost vertically from the incurved apex to the aperture; on the sides it is slightly rounded below the dorsum and then slopes regularly to the aperture; length and width of aperture nearly equal. Peristome sinuous.

Surface marked by fine, even striae.

P. indianensis resembles this shell in its angular dorsum, but does not have the row of dorsal spines which clearly distinguishes this shell from any *Platyceras* with which I am acquainted.

Formation and locality.

Jeffersonville limestone; Little Rock Creek, Cass County.

Platyceras lineare n. sp.

Pl. XVIII, figs. 3, 3a.

Shell small, depressed arcuate along the dorsal axis; apex minute, closely enrolled for one and a half volutions, beyond which the shell abruptly expands, spreading more upon the right than upon the left side. Dorsum gently rounded toward the aperture, abruptly rounded near the apex. Aperture oblique. Posterior half of the peristome deeply sinuate.

Surface marked by very fine concentric striae which are somewhat wrinkled on the upper part of the shell. The body whorl is marked by two distinct longitudinal color bands, one on each side of the dorsum; these do not extend quite to the closely enrolled part of the shell. These bands have a sepia brown color and show as distinctly on the creamy white surface of the shell as if the specimen were still living.

This species is probably more closely related to the *P. buculentum* type than any other. Its much smaller size and comparatively larger aperture distinguish it from that species. The peristome does not spread over the preceding volution as in *P. buculentum*. The color bands are unique, but may not be preserved in other specimens. Mr. Green's collection contains the only specimen I have seen.

Formation and locality.
"Middle Devonian" (Jeffersonville limestone); Falls of the Ohio.

Platyceras subcirculare n. sp.

Pl. XIX, fig 5.

Shell arched, the dorsal line of the body whorl forming a nearly perfect half circle. Apex minute, closely coiled against the apical whorls, shell gradually enlarging from the apex, sharply rounded on the dorsum. The aperture is characterized by a peculiar auriculate expansion near the posterior margin on each side of the shell, which appears to be most strongly developed on the right side, giving a heart-shaped outline. The peristome is turned backwards at the margin, spreading partially over the preceding volution.

Surface marked by fine arched striae. On the body whorl the shell is marked by a color band on each side of the dorsum; the band on the right side on nearing the apex approaches the axis of the shell and on the apical whorl follows the dorsum. A third less distinct

color band marks the right side of the shell just above the auriculate expansion, and extends from the aperture about half way to the apex.

The specimen figured belongs to the collection of Mr. C. K. Green. It is the only one which I have seen.

Formation and locality.

"Middle Devonian" (Jeffersonville limestone); Falls of the Ohio.

PTEROPODA.*

Coleolus tenuicinctum Hall.

Pl. XXIII, figs. 6,7.

C. tenuicinctum Hall, Pal. N. Y., Vol. V, Pt. II, 1879, Pl. 32, figs. 5-9; Pl. 32A, figs. 6-10.

Hall's description.—"Shell an extremely elongate, gradually and regularly tapering cone, having in the largest individuals a diameter of six millimeters at the largest extremity, with a length of seventy-five millimeters. Surface marked by fine closely arranged striae, or frequently with more distant oblique annulations, receding from the aperture or sinuate on the ventral side—the degree of obliquity depending upon the position of the fossil or the relation of the parts exposed to view. Interrupted longitudinal striae are visible in well preserved specimens."

This species is not uncommon, but well preserved specimens are rare. The specimens which I have are marked by fine regular concentric striae; there are no oblique annulations.

One specimen in Mr. Green's collection has a length of 2 9-10 inches and a width at the larger end of 3-10 of an inch. The specimens listed as *C. aciculum* on p. 80, Bull. Ann. Pal. No. 12, probably belong to this species.

Formation and locality.

Jeffersonville limestone and Sellersburg beds; Falls of the Ohio, Charlestown and Lexington.

TENTACULITES.

A. Annulations prominent, angular or subangular, form moderately elongate and slender. *T. scalariformis.*

AA. Annulations not very prominent, rounded, sides sloping, and form very elongate and slender. *T. dexithea.*

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* This group is treated as a division of the *Gastropoda* in the English edition of Zittel's Paleontology.

Tentaculites dexithea Hall.

T. dexithea Hall, Pal. N. Y., Vol. V, Pt. II, 1888, Supplement, p. 6, Pl. 114, figs. 18, 19.

Hall's original description.—"This species is distinguished from the *T. scalariformis* occurring in the Upper Helderburg limestone by its more elongate and slender form, and more sloping annuli."

The differences between the form occurring in the Pendleton sandstone and that found in the Devonian limestone are very slight and are due doubtless to the different conditions of sedimentation under which the two existed. The separation of the Pendleton form from *T. scalariformis* as a distinct species seems to be a distinction of doubtful value.

Formation and locality.

Pendleton sandstone; Pendleton.

Tentaculites scalariformis Hall.

Pl. XXIII, fig. 9.

T. scalariformis Hall, Pal. N. Y. Vol. V, Pt. II, p. 167, Pl. 31, figs. 3-11.

Hall's description.—"Form elongate conical, straight, somewhat more cylindrical in approaching the aperture; with the apex in well preserved specimens extremely attenuate and quite solid from one-fourth to one-third the entire length of the shell. Annulations prominent, subangular, sometimes rounded on the larger part of the cone, closely arranged and sharply angular near the apex, gradually increasing their distance, becoming less angular with the increase in the size of the shell, and obtuse and rounded towards the aperture; usually but little variation in character on the outer half of the length, where the spaces between are greater than the annulations. Interspaces and annulations, when well preserved, marked by fine, even transverse striae, of which nine or ten may be counted in the furrows, and half as many on the summit and sides of the annulations."

This species is rather common at some localities.

Formation and locality.

Sellersburg beds and Jeffersonville limestone; Clark County, Scipio, Lancaster, North Vernon, Bartholomew County, and Pipe Creek Falls.

Conularia sp.

Pl. XXIII, fig. 8.

Form of shell unknown; surface marked by numerous fine transverse ridges, of which there are from ten to fifteen in the space of one-fifth of an inch; the summit of each ridge is marked by from eight to ten minute pores in the space of one-tenth of an inch. The interspaces between the ridges are marked by extremely fine longitudinal lines.

Only one specimen, which is badly crushed, has been found. It occurs in the *Spirifer mucronatus* fauna of northern Indiana.

Formation and locality.

Sellersburg beds; Delphi.

CEPHALOPODA.

GYROCERAS.

A. Surface marked by transverse foliate expansions rising above the test. *G. jason.*

AA. Surface not marked by foliate expansions.

- b. Septa curving strongly backward in crossing the sides; volutions subquadrangular in transverse section. *G. indianensis.*
- bb. Septae curving very slightly backward in crossing the sides; volutions suboval in transverse section. *G. inelegans.*

Gyroceras jason Hall.

Pl. XXVII, fig. 1.

G. jason Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 381, Pl. 50, figs. 1-2.

Shell very large curved, making about one-third of a volution; robust and nearly circular in transverse section. Conch rather gradually enlarging.

Chamber of habitation and siphuncle not observed. Test has a thickness of about 8/50 of an inch. Surface covered by irregular lamellose lines of growth. Prominent transverse foliate expansions on the test mark the surface at regular intervals. These are usually distant from each other on the ventral side from one-half to one inch; they are directed toward the aperture, rising sometimes as much as an inch above the surface, and are somewhat crinkled. Traces of a low, sharp ridge a little to the left of the median line are preserved.

The specimen figured has a length of 10½ inches, and a diameter in the widest part of 3½ inches. This specimen does not show the "somewhat hexagonal" transverse section mentioned by Hall nor the

deep sinus ascribed to *C. jason*, but I am inclined to regard it as a representative of that type.

The specimen figured was collected by Mr. John Powers; it is the only one known to me.

Formation and locality.

Jeffersonville limestone; Lexington.

Gyroceras indianense n. sp.

Pl. XXIV, fig. 1; XXV, figs. 1, 1a.

Shell large, subovoid, discoid, making about two and a half or three volutions, which enlarge rather rapidly and are closely contiguous. Volutions rounded, subquadrangular, the transverse diameter somewhat greater than the dorso-ventral diameter; sides flattened, periphery and inner surface very gently convex. Septa separated on the periphery by a space equal to about one-third the dorso-ventral diameter; the width of the interseptal spaces on the periphery at any point is equal to about three times the width of the same spaces on the opposite surface. The septa describe graceful backward curves in crossing the sides, bending forward to the peripheral surface, which they cross in straight or slightly backward curving lines; the backward curve on the periphery, if developed, is much less marked than on the sides. Body chamber large, occupying about half the outer volution.

Siphuncle small, about midway between the center and the peripheral margin of the volution. The inner volution shows a line of small nodes marking each of the obtuse angles formed by the union of the sides with the dorsal and ventral surfaces of the volution. Surface markings elsewhere not preserved.

This shell agrees very closely with Meek's description of *Gyroceratites ohioensis* except in the direction of the septa, which he describes as curving backward more strongly on the peripheral surface than on the sides. In the specimens here described the reverse is true.

I have seen but two specimens of this fossil, both found by Mr. Taylor, of Hanover, Ind.

Formation and locality.

Jeffersonville limestone(?); Jefferson County.

Gyroceras inelegans Meek ?

Pl. XXVIII, fig. 1.

G. (Nautilus) inelegans Meek, Ohio Pal. Vol. I, 1873, p. 232, Pl. 21.

The specimen here figured is referred doubtfully to *G. inelegans*. It represents apparently about half of the body volution of an individual of that species.

Dorso-ventral diameter somewhat greater than the transverse diameter; broadly rounded on the periphery and rather sharply rounded on the dorsal side. Septa crossing the sides with a very slight posterior curve, their anterior faces very concave. Body chamber very large, forming about three-fourths of the length of the specimen.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Nautilus maximus (Conrad).

N. maximus Nettleroth, Ky. Foss. Shells, 1889, p. 196, Pl. 24, fig. 1.

Nettleroth figures this species from the Indiana Devonian. I have not seen it.

Formation and locality.

Sellersburg beds; Falls of the Ohio.

GOMPHOCERAS.

A. Surface marked by longitudinal ridges or striae.
- b. Shell gibbous or subglobose. *G. oviforme.*
- bb. Shell slender. *G raphanus.*

AA. Surface not marked by longitudinal striae.
- c. Chamber of habitation abruptly rounded at the front. *G. turbiniforme.*
- cc. Chamber of habitation gently rounded at the front. *G. minum.*

Gomphoceras turbiniforme M. and W.

G. turbiniforme Meek and Worthen, Geol. Surv. Ill., Vol. III, 1868, p. 444, Pl. 12, figs. 2a, b.

Meek and Worthen's description.—"Shell rather small, turbinate or subovate, very slightly unsymmetrical; section circular or nearly so; chambered part rapidly expanding, with sides slightly convex above. Nonseptate part very short, or three times as wide as long, rounding in abruptly above; aperture contracted, but exact form un-

known. Septa only moderately concave; nearly equidistant at all points, excepting near the center and the apex, where they are more crowded; at about the widest part of the shell, separated by spaces equaling one-eighth of its greatest diameter.

"Siphon small and marginal. Surface nearly smooth, or with only fine lines of growth."

The collections at hand contain three specimens of this species. In one of these specimens the aperture, the width of the nonseptate part, is equal to twice its length. The front of the shell rounds off abruptly to the aperture, which is margined by a process which projects slightly above the surface. The aperture is a transverse slit rounded at the ends with a straight upper margin; the lower lip has in the middle a deep rounded sinus whose width equals one-third the length of the aperture.

Formation and locality.

Sellersburg beds; Charlestown and Lexington.

Gomphoceras minum Hall.

Pl. XXV, fig. 3.

G. minum Hall, Pal. N. Y., Vol. VII, 1888, p. 34, Pl. 122, fig. 4.

Hall's description.—"Shell small, oviform; point of greatest transverse section on the anterior third of the tube. Chamber of habitation comparatively large and gibbous. Aperture small, trilobate. Air chambers two mm. in depth. Test marked by lines of growth. Length of specimen 30mm, greatest diameter 22mm. The shell of the individual described is silicified and many of the features are obscure."

The collections at hand contain four specimens of this species. They are characterized by their pear-shaped outlines, regularly rounded anterior extremities and trilobate apertures. One of the specimens shows the siphuncle to be submarginal. In some specimens the septa are more closely crowded at one side than at the other, giving them an unsymmetrical appearance, as in the specimen figured.

Formation and locality.

Sellersburg beds; Charlestown and Falls of the Ohio.

Gomphoceras oviforme Hall.

G. oviforme Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 344, Pl. 45, figs. 1-4; Pl. 46, figs. 6, 7; Pl. 94, figs. 6, 7.

One specimen in Mr. Green's collection is referred to this species with some doubt.

Shell straight, rather gibbous, oval in transverse section. Chamber of habitation long, the length equal to three-fourths of the width. Greatest width near the base of the chamber of habitation, which is slightly contracted posterior to the aperture. The four or five camerae next the chamber of habitation are of uniform size except the last, which is slightly smaller than the others. Sides of shell tapering very gradually toward the apex, which is not preserved.

Surface markings not preserved. The length of the shell is 2 9/10 inches; the chamber of habitation has a length of 1½ inches.

Formation and locality.

Sellersburg beds; Falls of the Ohio.

Gomphoceras raphanus Hall ?.

G. raphanus Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 347, Pl. 94, figs. 2-5, 10.

Some very poor specimens in the State Museum were listed under this species in the State Museum catalogue.* Their state of preservation will not permit of positive determination, and they may or may not belong to this species.

Formation and locality.

Sellersburg beds; Charlestown and Lexington.

Gomphoceras sp.

Pl. XXIX, fig. 1.

The specimen figured is a limestone cast, unsatisfactory for specific determination. It may be compared with *Gomphoceras eximum* Hall. The shell is vertically compressed, elliptical in cross section. Toward the apex the shell is slightly curved upward. The septa are moderately convex on their posterior faces.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

ORTHOCERAS.

A.	Transverse ridges with nodes in longitudinal ridges.	*O. caldwellensis.*
AA.	Transverse ridges without nodes.	*O. thoas.*

Orthoceras thoas Hall.

O. thoas Hall, Pal. N. Y., Vol. V, Pt. II, 1879, p. 261, Pl. 41, figs. 1-9; Pl. 78B, fig. 5; Pl. 79, fig. 13; Pl. 80, figs. 7, 8, 10, 11; Pl. 112, figs. 7-8.

*16th Ann. Rep. Ind. Dept. Geol. and Nat. Hist.

The collections from northern Indiana contain a section of a tube of this species measuring two inches in length and one and one-tenth inches in width at the widest part. Shell straight, very gradually expanding, circular in transverse section. Septa rather deeply concave. Surface marked by transverse annulations separated by flat or slightly concave interspaces one-tenth of an inch in width. The annulations are rather low rounded or obtusely angular ridges. Indistinct longitudinal striae mark the surface. The specimen is poorly preserved and if transverse striae have been present they are not preserved.

Formation and locality.

Jeffersonville limestone; Bunker Hill.

Orthoceras caldwellensis Miller and Gurley.

O. caldwellensis M. & G., Bull. Ill. State Mus. Nat. Hist. No. 11, p. 31, Pl. 4, figs. 1-2.

Miller and Gurley's original description.—"Shell straight, large, long, very slowly and regularly enlarging from the apex toward the mouth of the chamber of habitation. Only the middle part of the shell is preserved in our specimens. Chamber of habitation unknown. Transverse section subelliptical. Siphuncle subcentral. The shell is preserved on our specimen and the air chambers are not, therefore, exposed. The shell is widely and deeply annulated or transversely furrowed. The dividing ridges are nodose. The nodes are arranged in longitudinal rows. There are fourteen nodes on each transverse ridge, in the specimen, and hence there are fourteen longitudinal rows of nodes. A longitudinal line crosses each furrow from node to node, but it is nearly obsolete at the bottom of the furrows. The width of a furrow or distance between two nodes, at the larger end, is equal to one-third of the shorter diameter of the shell, but, at the smaller end of the specimen, the distance between two nodes is more than one-third of the greater diameter. The width of the annulations, therefore, does not bear a regular proportion to the diameter of the shell. There is an obscure node between the regular nodes, at the larger end, but none near the smaller end. The septum shown at the smaller end is highly arched, and it appears as if there is only one septum to correspond with each annulation. The shell is thick and the outer surface of the furrows shows no lamellose lines of growth, but, possibly, a better preserved specimen would show such lines."

This species is known only from the types.

Formation and locality.

"Upper Helderburg group;" Clark County.

Cyrtoceras expansum n. sp.

Pl. XXVI, fig. 1.

Shell rather large, moderately curved. Transverse section elliptical, the dorso-ventral and transverse diameters in the ratio of 8 to 11. Shell rapidly enlarging from the apex. Apex not preserved. Chamber of habitation large and gibbous, having a length equal to or greater than the width. Septa rather strongly concave on their posterior faces. Sutures regularly transverse. Siphuncle dorsal, about midway between the center and dorsal margins.

Surface marked by transverse closely arranged striae, and by somewhat stronger and more distant longitudinal striae. The latter are separated by spaces four or five times their own width.

This form does not seem to be very closely related to any other species with which I am acquainted. The position of the siphuncle near the dorsal margin distinguishes it sharply from most species of this genus.

Formation and locality.

Jeffersonville limestone; Bunker Hill.

Cyrtoceras sp.

Pl. XXV, fig. 2.

Shell arcuate, very rapidly expanding. Somewhat compressed, subovate in transverse section, the ventral surface strongly convex and the dorsal very slightly convex or nearly flat. Chamber of habitation not preserved. Septa thin, with a concavity in the posterior portion equal to their thickness; in the anterior portion the concavity is greater. Siphuncle on the ventral side, submarginal.

Surface marked by fine transverse striae which arch slightly backward in crossing the middle of the ventral side.

The specimen here figured is believed to represent a new species, but since the absence of the chamber of habitation prevents a full description, no specific designation will be proposed.

Formation and locality.

Sellersburg beds(?); Jefferson County.

Goniatites discoideus var. *ohioensis* Hall.

G. discoideus var. ohioensis Hall, 27th Rep. N. Y. State Mus. Nat. Hist., 1874, Pl. 13, figs. 18, 19.

I have seen but one fragmentary specimen of this gonatile.

Formation and locality.

Sellersburg beds; Lexington and Falls of the Ohio.

CRUSTACEA.

PHACOPS

A.	Pleural annulations of the pygidium dichotomous.	
b.	Axis of the thorax with row of spines.	*P. cristata.*
bb.	Axis of the thorax without row of spines.	*P. cristata* var. *pipa.*
AA.	Pleural annulations of the pygidium not dichotomous.	*P. rana.*

Phacops rana (Green).

Pl. XXXI, figs. 1, 1a, 1b.

Phacops rana (Hall and Clarke), Pal. N. Y., Vol. VII, 1888, p. 19, Pl. 7, figs. 1-11; Pl. 8, figs. 1-18; Pl. 8A, figs. 21-33.

This well known species is perhaps more common than any other trilobite in the Indiana Devonian. Complete individuals, however, are rare. The largest specimen observed has the following dimensions: Length of cephalon, 7/10 of an inch; thorax, 1 7/50 inches; pygidium, 5/10 of an inch; total length, 2 17/50 inches. The lenses in the eyes of the specimens figured here, which are from Mr. Green's collection, number respectively 69 and 82.

Formation and locality.

Jeffersonville limestone; Charlestown, North Vernon, Bartholomew County, Falls of the Ohio, Watson, Lexington, Lancaster and Little Rock Creek, Cass County.

Phacops cristata Hall.

P. cristata Hall and Clarke, Pal. N. Y., Vol. VII, 1888, p. 14, Pl. 6, figs. 1-13, 16-29; Pl. 8A, figs. 1-4.

The collection of Mr. G. K. Green contains a segment of the thorax of this species. It is flattened and dichotomous on the pleurae and bears the short, strong spine on the axis which is characteristic of this species. No other specimens of the species have been observed.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Phacops cristata var. *pipa* H. and C.

Pl. XXX, fig. 4.

P. cristata var. pipa H. & C., Pal. N. Y., Vol. VII, 1888, p. 18, Pl. 8A, figs. 5-18.

This variety is distinguished from *P. cristata* according to Hall and Clarke by the following characters: (a) Greatly inferior size; (b) absence of the axial row of spines; (c) smaller spines at the genal angles; (d) fewer annulations upon the pygidium; (e) smaller number of corneal lenses, varying from 23 to 45 for each eye.

Hall and Clarke record this variety from the Falls of the Ohio. A few pygidia from this locality in Mr. Green's collection are referred with some doubt to this species. These have from nine to ten annulations on the axis and six to seven on the pleurae; the anterior two or three of the latter are distinctly grooved near their distal extremities and near their junction with the axis, while their medial partition is marked by a very faintly impressed line or not at all.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

PROETUS.

A. Pygidium very small, with minute tubercles arranged in two or more rows on each annulation. *P. microgemma.*

AA. Pygidium not very small, with regularly arranged tubercles on the annulations.

- b. Lateral furrows on the glabella deep and prominent, glabella tapering anteriorly. *P. curvimarginatus.*
- bb. Lateral furrows on the glabella shallow and inconspicuous or obsolete, glabella not tapering anteriorly.
  - c. Posterior portion of the pygidium smooth. *P. crassimarginatus.*
  - cc. Posterior portion of pygidium with annulations similar to those on the anterior portion.
    - d. Cephalon very short without spines at the genal angles. *P. folliceps.*
    - dd. Cephalon not very short with long spines at the genal angles.
      - e. Annulations of the pygidium arching backward in crossing the summit of the axis. *P. macrocephalus.*
      - ee. Annulations of the pygidium not arching backward in crossing the axis.
        - f. Border of cephalon grooved by two furrows. *P. canaliculatus.*
        - ff. Border of cephalon not grooved by two furrows.
          - g. Glabella rather strongly convex. *P. clarus.*
          - gg. Glabella depressed. *P. latimarginatus.*

Proetus latimarginatus Hall and Clarke.

P. latimarginatus H. & C., Pal. N. Y., Vol. VII, p. 97, Pl. 22, figs. 7-12.

Hall and Clarke's original description.—"General form and proportions: Outline elliptical, length to width as two to one. Surface conspicuously trilobate, convex, deflected on the marginal area. Cephalon semielliptical in outline; border broad, flat, thickened by doublure and produced into stout spines at the angles of the cheeks. Length to width as 5 to 7.

"Facial sutures taking their origin close within the genal angles, passing forward very obliquely over the occipital ring to the eye lobe, cutting the anterior margin at points relatively distant, and approximating upon the doublure.

"Glabella depressed convex, slightly flattened above and posteriorly elevated on the axial line; long, conate extending to the frontal border. Width at the base greater than one-third the width of the shield. Lateral furrows obscure, but indications of three pairs may be observed. Occipital lobes comparatively large; occipital furrows narrow, bifurcating near the axial furrow to include the occipital lobes, and becoming very deep upon the cheeks; occipital ring broad and flat.

"Cheeks convex, depressed about the base of the eyes, thence somewhat abruptly deflected to the marginal sulcus and occipital furrow.

"Eyes comparatively small, approximate, attaining the elevation of the glabella. Palpebrum small; palpebral lobes depressed, obscure; palpebral sulcus shallow.

"Thorax subquadrate, length to width as two to three; margins nearly parallel; surface equally trilobate.

"Axis evenly arched, widest at the fourth segment and tapering thence regularly backward. Segments flattened, transverse.

"Pleurae flat for one-half their width and thence deflected in a moderately sharp curve to the margin. Each segment grooved for two-thirds its length, and beveled upon the outer third by the articulating plane.

"Pygidium parabolic in outline, length to width as three to five; evenly convex; border broad, flat or slightly sloping.

"Axis prominent and evenly tapering to an abrupt and somewhat elevated termination just within the posterior border, with which it is connected by a low ridge. Indications of seven or eight transverse annulations appear on the axis, exclusively of the articulating ring, which is more conspicuous than any of the others.

"Pleura evenly sloping to the lateral and posterior margins. Articulating ring very conspicuous; annulations obscure, almost obsolete. Four are visible in favorably preserved specimens, and all are depressed above and faintly grooved."

This species is not uncommon in the Pendleton sandstone from which the types were obtained, but I have not recognized it elsewhere.

Formation and locality.

Pendleton sandstone; Pendleton.

Proetus canaliculatus Hall.

P. canaliculatus H. & C., Pal. N. Y., Vol. VII, 1888, p. 107, Pl. 20, figs. 10, 11; Pl. 23, figs. 10, 11.

Hall and Clarke's description.—"The species is characterized by its violin-shaped glabella (genus *Aeonia,* Burmeister), constricted at the anterior angle of the eye, and broadly rounded on the anterior extremity. Its length would be more than two-thirds the length of the cephalon, and its width apparently somewhat less than one-third that of the cephalon. The transverse furrows are indistinct upon the crust, but appear to consist of three pairs and the accessory pair. The first pair visible is transverse, and the posterior pairs are inclined backward. All the glabellar lobes are faint. The occipital lobes are conspicuous; the occipital furrow narrow and deep; the occipital ring moderately broad and flattened. The border is very broad and flat, and is grooved along the anterior limbus by two furrows, the anterior of which is narrow and close upon the edge, the other is broad and is separated from the frontal margin of the glabella by a rounded ridge. Upon the cheeks these grooves become shallower and reduced to two planes, the interior and broader one horizontal, the anterior narrower and beveling. At the genal angles the border is produced into moderately long and stout spines which are ridged upon the surface, and minutely curved at the tip. The eyes and palpebral lobes are comparatively large, the orbital ridge elevated, the cheeks flattened at their summit below this ridge, abruptly curving to the marginal and occipital furrows. The surface is smooth upon the border, finely granulose upon the glabella and pustulose upon the flattened summits of the cheeks. The doublure is strongly rounded and incurved, somewhat excavate at the genal angles, sharply convex and ridged upon the genal spines. Its surface is marked by longitudinally parallel, lamellose lines."

Formation and locality.

Hall and Clarke record the species from the "Corniferous limestone" at the Falls of the Ohio.

Proetus curvimarginatus Hall and Clarke.

P. curvimarginatus H. & C., Pal. N. Y., Vol. VII, 1888, p. 94, Pl. 22, figs. 13-19.

This species is readily distinguished from *Proetus macrocephalus*, to which it is most closely related, by its deeply furrowed and rapidly tapering glabella.

The types were found in the Pendleton sandstone at Pendleton.

Proetus microgemma Hall and Clarke.

P. microgemma H. & C., Pal. N. Y., Vol. VII, 1888, p. 109, Pl. 22, figs. 33-34.

Hall and Clarke's original description.—"Several detached pygidia afford certain characteristic features in which they differ from described species. The shield is small and transversely semielliptical in outline, convex, longitudinally arched, distinctly and equally trilobate. The axis is elevated, tapering with slightly rounded margins to a blunt and somewhat elevated termination just within the border. It is somewhat appressed at the sides just above the axial furrows, bears eleven annulations which are angulated at the sides, and posteriorly recurved over the median line. Upon the axial line each bears a strong tubercle. The pleurae are depressed below the axis, slightly flattened above and equally deflected to the lateral and posterior margins. Each bears seven or eight annulations which are grooved by fine impressed lines. The border is thickened, moderately and equally broad throughout its extent; it is encroached upon by the articulating ring and slightly by the first two or three annulations. The surface is covered with minute and distinct tubercles, which are irregularly disposed upon the annulations of the axis, but are arranged in two or more rows on each annulation. A very young example, measuring 2mm in length and 3mm in width, shows nine annulations on the axis and ten on the pleurae; the margin is less thickened than in the later stages of growth, all the pleural annulations encroaching upon it. The annulation is also more distinct than in larger specimens. An average specimen measures 6mm in length and 9mm in width."

Formation and locality.

"Corniferous limestone;" Falls of the Ohio.

Proetus folliceps Hall and Clarke.

Pl. XXX, figs. 10, 10a.

P. folliceps H. & C., Pal. N. Y., Vol. VII, 1888, p. 101, Pl. 29, figs. 3-8.

Hall and Clarke's original description.—"General form and proportions: Body elongate, outline elliptical, lateral margins nearly parallel. Length to width as eight to five. Surface convex, anteriorly gibbous, conspicuously and subequally trilobate. Cephalon short, semicircular, border flat, moderately broad, horizontal anteriorly, becoming deflected toward the genal extremities, which are broadly rounded and not produced. Surface very convex, equally trilobate, length to width as one to two. The facial sutures take their origin just within the genal angles, run very obliquely across the occipital ring to the outer angle of the occipital lobes, thence rise abruptly to the eye lobes, and pass with slight divergence down the steep frontal slope, curving and approaching each other at the edge of the frontal border and uniting upon the doublure.

"Glabella subpyriform, very convex, longitudinally arched, rising abruptly on all sides from the lateral furrows, which are not deeply impressed; gibbous on the anterior slope, slightly flattened at the summit. Length equal to four-fifths the length of the cephalon; width at the base more than one-third that of the cephalon. Four pairs of lateral furrows and one pair of accessory furrows are discernible upon the cast of the lower surface, but upon the crust only the stronger of them can be seen, as faint lines interrupting the ornamentation. The first pair is situated at about one-third the length of the glabella from the anterior margin, and appear as faint elongate pits not distant from the marginal furrow. The other three pairs are longer and inclined backward, none except the fourth pair extending to the marginal furrow. The accessory furrows take their origin just in front of the proximal ends of the fourth furrow and are strongly inclined backward. The occipital lobes are moderately strong in the cast, but are inconspicuous where the crust is retained. Occipital furrows narrow, the anterior side nearly vertical and the posterior side almost horizontal, widening on the cheeks and continuous with the marginal sulcus. Occipital ring broad, flat, narrowing to the axial furrows and widening again to the genal angles, bearing a small pointed tubercle upon the axial line. Cheeks grooved and depressed about the orbital lobe, thence abruptly deflected to the broad margin. Eyes approximate, prominent, elevated to almost the height of the glabella; orbital ring conspicuous; palpebral lobe small;

palpebral furrow elevated and moderately deep. Thorax subrectangular, margins nearly parallel. Length to width as one to one and three-tenths.

"Axis arched.

"Pleurae flattened above for one-half their width, and thence somewhat abruptly deflected. The segments are transverse, somewhat flattened, grooved upon the pleurae and beveled for one-half their length. Pygidium subsemicircular, border broad, thickened and rounded. Surface convex, sloping more abruptly at the sides than posteriorly. Axis having less than one-third the width of the shield, tapering to a broad and blunt termination, considerably within the posterior margin. It bears seven or eight annulations, which bend forward for a short distance within the axial furrows, are there sharply angulated and cross the axial line in a broad curve.

"Pleurae with seven or eight annulations, each of which is broad, low, often indistinct, and very faintly grooved, all becoming obsolete upon the border. Length to width as one to one and eight-tenths.

"*Dimensions.*—An average adult affords the following measurements:

	Body.	*Cephalon.*	*Thorax.*	*Pygidium.*
Length	43 mm.	12 mm.	18 mm.	13 mm.
Width......................	27 mm.	27 mm.	23 mm.	20 mm.

"The smallest individual observed measures 24mm in length and 14mm in width."

This species occurs rarely at Pipe Creek Falls.

Formation and locality.

Jeffersonville limestone; Pipe Creek Falls.

Proetus crassimarginatus Hall.

Pl. XXX, figs. 1, 1a, 2, 5, 6.

P. crassimarginatus H. & C., Pal. N. Y., Vol. VII, 1888, p. 99, Pl. 20, figs. 6-8, 20-31; Pl. 22, figs. 20-26; Pl. 15, fig. 8.

Glabella large, subquadrate; surface convex, slightly flattened on top, marginal furrows shallow; three to four pairs of lateral furrows, directed obliquely backward; these are developed on the lower surface of the glabella and reveal themselves in specimens which are not exfoliated only by their darker color showing through the semitransparent crust. Occipital lobes are relatively small but well defined; occipital furrow narrow and shallow. The border of the cephalon is usually narrow and much thickened in front.

Thorax composed of ten segments; axis broad and strongly arched; pleurae flattened for half their width, then sloping abruptly to the margin; the segments are flattened and grooved upon the pleura.

Pygidium semiovate, convex, sloping regularly to the lateral and posterior margin; axis strongly arched both transversely and longitudinally, tapering to an obtuse termination. The anterior end is marked by from four to ten annulations, the posterior lateral area being smooth. In exfoliated pygidiae a larger number of indistinct annulations may be counted. In crossing the summit of the axis the annulations arch backward slightly.

The pygidiae and glabella of this trilobite are abundant at Pipe Creek Falls, but I have seen no complete individuals.

Horizon and locality.

Jeffersonville limestone and Sellersburg beds; Pipe Creek Falls, Charlestown, Falls of the Ohio.

Proetus clarus Hall.

Pl. XXX, figs. 8, 9, 12.

P. clarus H. & C., Pal. N. Y., Vol. VII, 1888, p. 104, Pl. 20, figs. 12-14; Pl. 22, figs. 28-30.

The collections at hand contain several specimens of the glabella and free cheeks of this species. Partially exfoliated specimens show three pairs of transverse furrows on the glabella which are directed obliquely backwards. Other specimens show only the posterior pair, which are bent abruptly backwards about the middle of their length. The anterior border is very broad, flat or with a shallow groove toward the front. Occipital furrow narrow and deep; occipital lobes rather large.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio, Burnsville, Bartholomew County, Lexington, Bunker Hill and Pipe Creek Falls.

Proetus macrocephalus Hall.

Pl. XXX, figs. 7, 11.

P. macrocephalus H. & C., Pal. N. Y., Vol. VII, 1888, p. 116, Pl. 21, figs. 10-21; Pl. 23, figs. 30-31.

Hall and Clarke's original description.—"General form and proportions: Outline elliptical. Surface depressed convex, distinctly and subequally trilobate. Length and width as one and five-tenths to one.

"Cephalon semicircular or lunate, margin slightly thickened and deflexed, produced at the genal angles into acute spines. Surface very convex in normally preserved specimens; depressed in the usual state of preservation. Length to width as one to two.

"Facial sutures normal. Glabella subconate, sides broadly tapering to the anterior extremity, where it is closely appressed upon the narrow reflexed margin. Width three-fourths the length. Surface convex, anterior slope normally abrupt or vertical, curving posteriorly and becoming horizontal at the occipital furrow. Under normal preservation only a single pair of lateral furrows is visible. These are the fourth or basal furrows and are very strong and deep, taking their origin nearly opposite the anterior angle of the eye and extending to the occipital furrow, thus forming two strong conspicuous lobes. Upon casts of the lower surface and in extremely rare instances upon the dorsal surface, there is evidence of the first, second and third pair of furrows, with faint indications of the accessory furrows. Occipital lobes prominent; occipital furrow narrow, broadly bifurcating about the occipital lobes, and becoming deeply impressed and broadened upon the cheeks; occipital ring broad and posteriorly convex, narrowing upon the cheeks. Eyes not large, lunate; palpebral lobe inconspicuous; palpebral sulcus narrow and deep.

"Cheeks deeply grooved about the orbit of the eye, and abruptly depressed to the broad marginal sulcus.

"Thorax subrectangular; surface convex and equally trilobate; length to width as one to one and eight-tenths; composed of ten segments which are arched upon the axis and considerably elevated above the pleurae, obliquely flattened and transverse. The pleurae are flattened for less than one-half their width and abruptly deflected to the margin; segments sulcate anterior and posterior limbs nearly equal, the former becoming abruptly obsolete at the fulcrum.

"Pygidium large, semielliptical convex; length to width as two to three.

"Axis having less than one-third the width of the shield upon the anterior margin, and tapering to a blunt termination within the border. Annulations thirteen or fourteen with an anterior bend near the margins, and a broad curve near the median line; in most individuals the annulations are slightly angulated along the axial line, each sometimes bearing a strong tubercle.

"Pleurae depressed in a more or less abrupt curve to the margin, bearing eleven or twelve flattened annulations, which are separated by moderately strong sulci. Each annulation is faintly grooved by a fine impressed line, which is sometimes almost or quite obsolete.

Border broad, becoming excavate and slightly reflexed posteriorly; all the annulations except two becoming obsolete upon reaching it. Doublure broad, reaching to the termination of the axis.

"Surface ornamentation.—The cephalon is covered with low tubercles which become obsolete upon the anterior portion of the glabella and the depressed areas of the cheeks. Upon the thorax and pygidium each segment and annulation is ornamented with granules; these upon the latter sometimes appear to be arranged in two rows, one upon each limb of the pleural annulations. In rare examples a row of small tubercles is noticeable along the axial line on both thorax and pygidium, beginning with a faint tubercle upon the occipital ring, the next being at the third or fourth segment thence backward, becoming stronger toward the apex of the axis."

The glabella and pygidium of this species occurs rather abundantly in the limestone at Pipe Creek Falls. The specimens seem to agree perfectly with Hall's figures and descriptions of the New York specimens.

Horizon and locality.

Jeffersonville limestone; Pipe Creek Falls and Bunker Hill.

DALMANITES.

A. Pygidium having two or more spines projecting from the border.
- b. Spines on border of pygidium two in number. Frontal border of the cephalon with tooth-like denticulations.
  - c. Denticulations eleven, each of the pleurae of the pygidium with ten annulations, genal angles produced into spines extending to fourth or fifth thoracic segment. *D.* (*Odontocephalus*) *aegeria.*
  - cc. Denticulations nine, each of the pleura of pygidium with eight to nine annulations, genal angles obtuse, or produced into minute spines. *D.* (*Odontocephalus*) *selenurus.*
- bb. Spines on border of pygidium more than two. Frontal border of cephalon without tooth-like denticulations. Pygidium with ten or more spines on each of its lateral margins. *D.* (*Coronura*) *aspectans.*
  - dd. Pygidium with five spines on each of its lateral margins.
    - e. Annulations of the pleurae not sulcate, spines of pygidium long and rounded. *D.* (*Cryphaeus*) *pleione.*
    - ee. Annulations of the pleurae sulcate, spines of pygidium not very long and somewhat flattened. *D.* (*Cryphaeus*) *boothi* var. *calliteles.*

AA. Pygidium not having two or more spines projecting from the border.
- f. Pygidium with a row of short spines along summit of the axis. *D. calypso.*

ff. Pygidium without a row of spines along the summit of the axis.
g. Annulations on the pleurae grooved from end to end.
D. (*Hausmannia*) *pleuroptyx.*
gg. Annulations on the pleurae grooved only near their distal extremities.
D. (*Chasmops*) *anchiops.*

Dalmanites (*Cryphaeus*) *pleione* Hall and Clarke.

Dalmanites (Cryphaeus) pleione H. & C., Pal. N. Y., Vol. VII, 1888, p. 41, Pl. 16A, fig. 2.

This species is at present known only by the type specimen, a pygidium, which, according to Hall and Clarke, closely resembles the pygidia of the young of *D. boothi* var. *calliteles.*

Horizon and locality.

Sellersburg beds ("Hydraulic limestone"); Falls of the Ohio.

Dalmanites (*Cryphaeus*) *boothi* var. *calliteles* Green (H. and C).

Pl. XXXI, figs. 3, 4.

D. (Cryphaeus) calliteles H. & C., Pal. N. Y., Vol. VII, 1888, p. 45, Pl. 16, figs. 5-22; Pl. 16A, figs. 9-17.

Only three or four imperfect cephala of this species have been seen. The accompanying figure indicates the character of one of those fairly well except that the axis is indicated rather wider than it should be.

My collections contain about twenty-five pygidia. The pygidium is subtriangular, depressed, with elevate axis. Axis with about twelve to fourteen annulations, tapering regularly and ending abruptly just within the posterior border.

Pleurae having each five strongly sulcate annulations; the posterior limb of each becomes obsolete near the margin while the anterior limb is produced beyond the margin in a slightly flattened spine. A spine somewhat shorter and broader than the others is produced from the posterior extremity.

The thorax has not been observed.

This trilobite has been found at only one locality, where it is abundant.

Formation and locality.

Jeffersonville limestone; Little Rock Creek, Cass County.

Dalmanites (Chasmops) anchiops (Green).

Pl. XXXI, figs. 2, 2a, 2b.

D. (Chasmops) anchiops Hall, Pal. N. Y., Vol. VII, 1888, p. 59, Pl. 9, figs. 1-6, 10, 12, 13; Pl. 10, figs. 1-14.

Pygidium subtriangular, rather depressed. Posterior extremity produced, curving slightly upward, terminating in a sharp spine. Axis having less than one-half the width of one of the pleurae at the anterior extremity, tapering regularly to the low rounded posterior extremity; the axis is composed of fourteen broad transverse annulations. Pleurae divided into ten broad flattened annulations which extend nearly to the margins; the annulations are finely grooved for about one-third their length near the margin of the pleurae. The annulations are separated by interspaces having less than one-half their own width. The surface of the annulations of the pygidium are rather coarsely granular.

The above is a description of a pygidium in Mr. Green's collection. This species is comparatively rare; it has not been observed in northern Indiana.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio and Utica.

Dalmanites (Chasmops) calypso H. and C.

Pl. XXX, fig. 3.

D. (Chasmops) calypso H. & C., Pal. N. Y., Vol. VII, 1888, p. 64, Pl. 11a, figs. 19-22.

Pygidium wide, subtriangular, axis much elevated above the pleurae.

Axis sharply angulated upon the median line, sides appressed; composed of thirteen closely set transverse annulations, each with a short spine or spinose node at the summit.

Pleurae rather broad, moderately convex toward the anterior end, sloping abruptly from the axis to the margin posteriorly; annulations flattened, twelve in number and distinctly grooved; border wide.

The pygidium here figured and described is the only representative of this species which I have seen; it belongs to Mr. G. K. Green.

Formation and locality.

Sellersburg beds; Charlestown.

Dalmanites (*Odontocephalus*) *selenurus* (Hall and Clarke).

D. (Odontocephalus) selenurus H. & C., Pal. N. Y., Vol. VII, 1888, p. 49, Pl. 11B, figs. 15-21; Pl. 12, figs. 1-13.

This species is represented in collections belonging to the U. S. Geol. Surv. which were made by the writer but which are not now accessible.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Dalmanates (*Coronura*) *aspectans* Conrad (Hall and Clarke).

Asaphus aspectans Con., Fifth Ann. Rep. Pal. N. Y., 1841, p. 49, fig. 9.

Dalmanates ohioensis Meek, Proc. Acad'y Nat. Sci. Phil., 1871, p. 91.

D. (Coronura) aspectans (H. & C.), Pal. N. Y., Vol. VII, 1888, p. 33, Pl. 13, figs. 1-11, 13.

Conrad's original description.—"A small portion of the buckler and one eye only is visible, but the eye is of extraordinary height, the margins parallel, and the lenses arranged in parallel longitudinal lines, small and very numerous."

This species is recorded by Hall and Clarke from the "Corniferous limestone" at the Falls of the Ohio. I have not observed it.

Dalmanites (*Hausmannia*) *pleuroptyx* Green (Hall?).

D. (Hausmannia) pleuroptyx Hall, Pal. N. Y., Vol. VII, 1888, p. 28, Pl. 11a, figs. 1-3.

Two pygidia are referred with some doubt to this species.

Form subtriangular, flattened or slightly convex.

Axis regularly tapering to a low rounded termination, and composed of from 16 to 19 transverse annulations. The pleurae are broad, rather flat on top and rounding somewhat abruptly to the margins. The annulations are thirteen in number, grooved from the axis to the margin, and rather strongly curved near their distal extremities towards the posterior end of the pygidium. The interspaces separating the annulations usually equal and sometimes exceed the width of the latter. The last five or six annulations are directed very strongly backwards. The surface of the pygidium is rather finely granulose.

Formation and locality.

Jeffersonville limestone; Falls of the Ohio.

Dalmanites (*Odontocephalus*) *œgeria* Hall.

Pl. XXXI, fig. 5.

Cephalon.—Outline as shown in the drawing. Border rather broad, nearly horizontal in front, sloping rather steeply downwards at the sides. The portion between the ends of the facial sutures is composed of eleven tooth-like processes which gradually decrease in size away from the median process; these processes are constricted at their bases, but widen towards the front so that their outer margins are in contact; partial exfoliation shows the walls of these finger-like processes to be double.

The glabella is subpentagonal, gently convex, sloping rapidly downwards toward the front. Surface minutely punctate. First lateral furrow oblique. First and second lateral lobes large and elevated. Axial portion of the glabella between anterior lateral lobes rounded and depressed. Occipital furrow narrow, moderately deep.

Eyes elevated above any other portion of the head; from the genal angles they present the outline of a nearly perfect truncated cone; the visual surface covers about three-fourths of the lateral surface of the cone. Palpebral lobe greatly depressed; palpebrum not prominent; lenses arranged in regular vertical lines and numbering about 110.

Cheeks flattened, separated from the eyes by a flat narrow terrace at the top. A shallow furrow extends from the anterior angle of the eye to the anterior lateral angle of the glabella, thence round the front of the glabella.

This species is represented in Mr. Green's collection by a single cephalon which is the only specimen which I have seen. It is referred to *D. aegeria* rather than to *D. selenurus* because the frontal denticulations agree in number with those in the former species. The parts which should show the other points of difference between these two closely related species are not preserved.

Formation and locality.
Jeffersonville limestone; Falls of the Ohio.

Calymene platys Green.

C. platys Hall, Pal. N. Y., Vol. VII, 1888, p. 1, Pl. 1, figs. 1-9; Pl. 25, fig. 1.

This species has not been observed by me. It is reported by Hall and Clarke from the "Upper Helderburg" at the Falls of the Ohio.

Lichas sp.

Pl. XXXI, fig. 6.

The collection of Mr. Green contains fragments of the cephalon and genal spines of a Lichas which may belong to *L. (Conolichas) eriopis*. The genal spine is closely studded on the upper surface and posterior with short strong spines, and on the anterior margin with numerous small tubercles.

Formation and locality.
Jeffersonville limestone; Falls of the Ohio.

ON A SMALL COLLECTION OF BATRACHIANS WITH DESCRIPTIONS OF TWO NEW SPECIES.

BY W. S. BLATCHLEY.

While collecting mollusca in southeastern Tennessee in the summer of 1900, Mr. L. E. Daniels of Laporte, Indiana, picked up six specimens of salamanders and placed them in a flask of alcohol which by chance he had with him. A few months after his return he kindly presented the specimens to me, and on examining them carefully I was agreeably surprised to find four species represented, of which two are evidently undescribed.

After sending specimens to Washington, D. C., for comparison with the known types represented in the Smithsonian Institute, and having my surmises as to the undescribed species verified, I have concluded to publish the descriptions in this connection. The species represented in the collection were as follows:

DESMOGNATHUS NIGRA (Green).

One specimen of this large black salamander was taken and several others seen. According to Cope "it is abundant in the streams of the rocky ravines and cold springs in the remostest depths of the forests of the Alleghany Mountain ranges from Pennsylvania southwards. It seeks concealment with great activity under loose stones and slabs of slate and is not easily captured. Sometimes it snaps fiercely but harmlessly and throws its body into contortions." The specimen at hand has the ground color of bluish-black, broken on the lower surface in front of gular fold, and on sides from posterior border of eye to front limb, by numerous small dots and splotches of brownish yellow. Otherwise it agrees with Cope's description.*

Its measurements are as follows: Total length, 143 mm; snout to posterior end of cloaca, 82 mm; snout to gular fold, 21.5 mm; width of head, 14 mm; distance from axil to groin, 53 mm.

* Batrachia of N. Am., p. 198.

Spelerpes sp. ?

A single specimen of a small *Spelerpes* which resembles *S. ruber* Daudin in form and in arrangement of vomero-palatine teeth, and *S. maculicaudus* Cope in color, was in the collection. The ground color is bright orange-yellow which, on the top and sides of the head, body and basal third of tail, is irregularly spotted with numerous small black dots.* The margins of both jaws are also almost covered with elongated black spots. With this latter exception the color is the exact facsimile of that of *S. maculicaudus.* The tail, however, is strongly compressed throughout its full length and is much shorter proportionally than in *maculicaudus.*

Measurements: Total length, 78 mm; snout to cloaca, 49 mm; snout to gular fold, 10 mm; width of head, 8 mm; distance from axil to groin, 31 mm.

It is impossible to say just where this specimen belongs. It may be an immature form of *S. ruber.* If so the spots become larger and more numerous in the adult. It may be the young of the next species, but the position of the parasphenoid teeth which, in the specimen at hand, are nearly contiguous, would seem to disprove this. The ground color is also much lighter and the spots more numerous.

Spelerpes danielsi sp. nov.

Groups with *S. ruber* Daudin but differs from that species in the much greater distance separating the series of parasphenoid teeth; in the larger and more depressed head; in the presence of prominent subnareal processes, and in color; the entire dorsal surface to middle of sides being (after immersion in alcohol) a light chocolate brown with fewer and more widely scattered black spots than in *ruber,* the throat reticulate with black, the remainder of the under surface light brownish gray, immaculate.

Palatine teeth originating behind and extending outward beyond the inner nares; forming an abrupt rectangle and continuous with the parasphenoid series; the latter strictly parallel and separated throughout their full length by a space almost 2 mm in width, or more than twice the width of each patch of teeth. Head wider and more depressed than in *ruber;* the greatest width contained 1.36 times in distance from tip of lower jaw to gular fold. Anteorbital ridges prominent; the interorbital space dis-

*These dots are much smaller and more widely scattered than in typical specimens of *S. ruber* Daudin.

tinctly wider and the snout longer and broader than in specimens of *ruber* of the same size. Upper jaw slightly overlapping the lower and bearing on its margin immediately below each nostril a tubercle which is connected with the nostril by a slit at right angles to the nasal opening.*

Body subcylindrical, elongate, its length 4.3 times the distance from tip of snout to gular fold. Tail shorter than body, its distal two-thirds strongly compressed and bearing an acute membranous flap or keel along the median line of its dorsal surface Limbs comparatively short, weak; when appressed lacking 7½ intercostal spaces of meeting. Digits unwebbed; the third finger half as long again as the second and fourth, which are of equal length; the third toe slightly longer than the fourth, and twice as long as the second and fifth, which are equal. Gular fold distinct; costal grooves 16, including the one in axil. Skin of back and lower surface smooth; that of the intercostal spaces, and sides and under part of head, thickly beset with shallow pits.

Ground color of dorsal surface of entire body a light chocolate brown, bearing widely scattered, irregular shaped dots of black, except on distal two-thirds of tail where they are lacking. On the middle of sides the chocolate brown gives way to a light grayish brown or putty color, which is immaculate except in front of the gular fold, where there are many spots and reticulations of black on the throat and margins of both jaws. In one of the specimens the ground color of the lower half of intercostal spaces is broken with many small yellowish points and dots.

Measurements of larger specimen: Total length, 160 mm; snout to posterior end of cloaca, 95 mm; snout to gular fold, 18 mm; width of head, 12.5 mm; length of fore limb, 17.5 mm; of hind limb, 19.5 mm; of tail, 65 mm; distance from axil to groin, 62 mm.

It was at first thought that this might be the *S. ruber montanus* of Baird, but Dr. L. Stejneger, of the Smithsonian Institute, to whom one of the specimens was sent for comparison with typical examples of that form, writes: "Your specimen is certainly not *S. montanus,* as one of the essential characters of that form is the excessively close approximation of the two rows of parasphenoid teeth on the median line; whereas your specimen has them more apart than any one in our large series."

*These subnareal processes are wholly wanting in *S. ruber*, *S. longicaudus* (Green) and *S. bilineatus* (Green), but are quite prominent in the adults of *S. maculicaudus* (Cope).

Two specimens are in the writer's collection from Sevier County, Tennessee, collected by Mr. L. E. Daniels, to whom I dedicate the species.

Plethodon jordani sp. nov.

Allied to *P. glutinosus* (Green) in form, size, and arrangement of palatine and parasphenoid teeth, but differing from that species by possessing longer and more slender digits, and in color; the bluish-white blotches and specks of *glutinosus* being wholly lacking, and an orange yellow bar being present on the sides of head and neck.

The series of palatine teeth extend slightly outward beyond the inner nares and are separated medially from each other by a short interspace and from the parasphenoid series by a little longer one; the parasphenoid patches contiguous along the median line. Head distinctly wider than body; proportionally shorter, broader and more depressed than in *glutinosus;* more distinct from the body than in that species; the greatest width, at angle of jaws, contained 1.3 times in distance from tip of lower jaw to gular fold. Snout short and blunt. Body sub-cylindrical, elongate, its length 3.8 times the distance from tip of snout to gular fold; more depressed anteriorly than in *glutinosus.* Tail slightly longer than head and body, the proximal third cylindrical, the distal two-thirds slightly compressed and tapering gradually to the pointed tip. Limbs relatively weak, when appressed lacking two intercostal spaces of meeting; the digits, when compared with those of *glutinosus*, notably long and slender; the third finger perceptibly longer than the second (4 mm in length); the third and fourth toes equal (almost 5 mm) in length, the webbing at base thinner and less evident than in *glutinosus.* Gular fold distinct; costal grooves 14. Mucous pores of back and sides less numerous and smaller than in *glutinosus.*

Color, after immersion in alcohol, bluish black, immaculate except on sides of head and neck where a brownish-red (in life, according to Mr. Daniels, orange yellow) band, 3½ to 4 mm in width, extends from posterior border of orbit to gular fold. Lower side of head paler, perhaps with a yellowish tinge in life.

Measurements of larger specimen: Total length, 124 mm; snout to posterior end of cloaca 67 mm; snout to gular fold, 14 mm; width of head, 10 mm; length of fore limb, 16.5 mm; of hind limb, 19.5 mm; of tail, 64 mm; distance from axil to groin, 37 mm.

Two specimens in the writer's collection, from Sevier County, Tennessee.

To Dr. David S. Jordan, President of Stanford University, California, who first guided my wandering footsteps into the highways and byways of scientific research, this handsome species of salamander is respectfully inscribed.

Since the above was in print I have learned from Mr. Daniels that the specimens mentioned were taken on the side of Mt. Collins and at Indian Pass, at an altitude of 3,000 to 5,000 feet. Both of the new species were observed a number of times on the way from Thunder-head Mountain, Blount County, to Indian Pass, and a dozen or more individuals of each could have been taken. They were found beneath old moss-covered logs, usually at some distance from water.

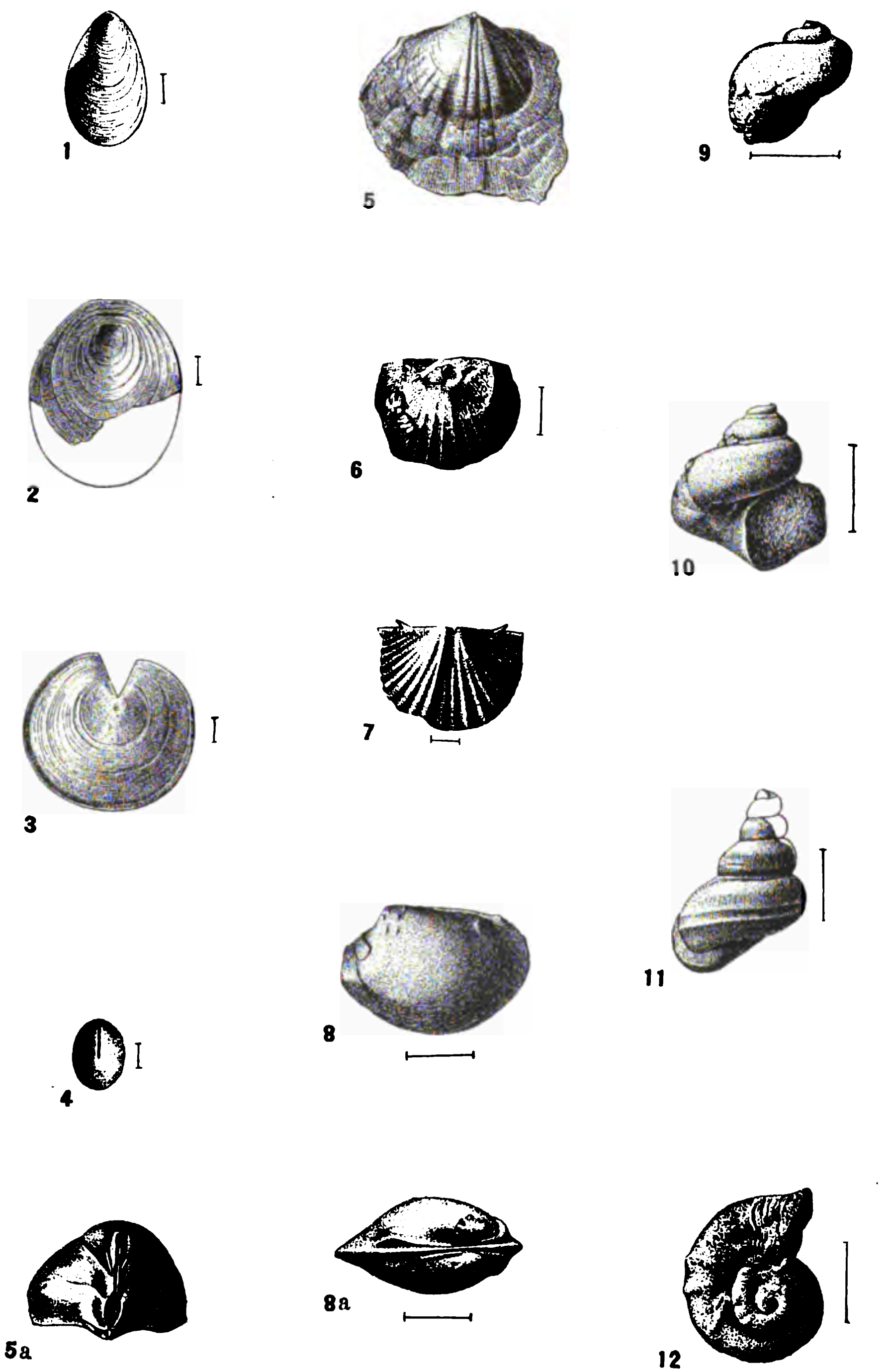
PLATES FOR PAPER

ON

Devonian Fossils and Stratigraphy

OF INDIANA.

PLATE I.



NEW ALBANY SHALE—DEVONIAN.

PLATE II.

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Fig. 1. *Goniatites delphiensis* n. sp.. 577

Side view of type specimen showing mass of pyrites attached.

Fig. 1a. Peripheral view of the same.

New Albany shale; Delphi.

Fig. 2. *Goniatites delphiensis* n. sp.. 577

View of specimen showing weak transverse ridges.

New Albany shale; Delphi.

Fig. 3. *Goniatites delphiensis* n. sp.. 577

Specimen showing transverse ridges only on the inner whorls.

New Albany shale; Delphi.

Fig. 4. *Goniatites wabashensis* n. sp.. 577

Lateral view of type specimen.

Fig. 4a. Ventral view of the same.

New Albany shale; Delphi.

Figs. 5–7. *Spathiocaris emersoni*.. 579

New Albany shale; Delphi.

Fig. 8. *Orthoceras sp*.. 578

New Albany shale; Delphi.

Fig. 9. *Styliola fissurella*.. 576

New Albany shale; Scipio.


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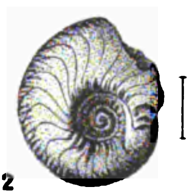
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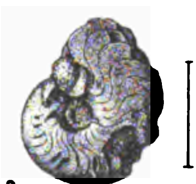
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NEW ALBANY SHALE—DEVONIAN.

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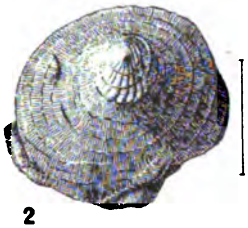
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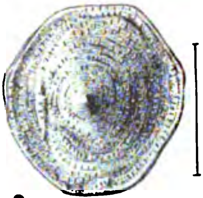
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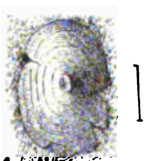
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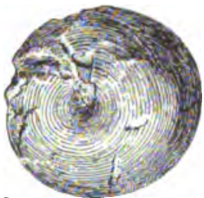
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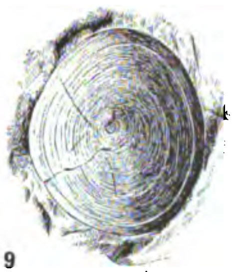
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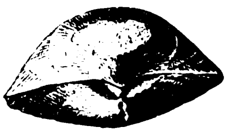
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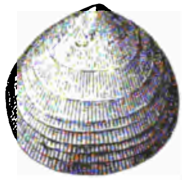
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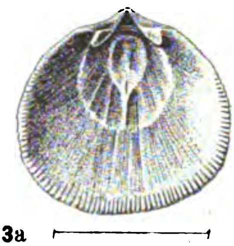
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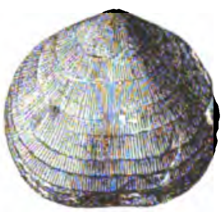
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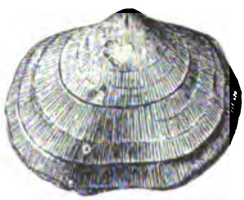
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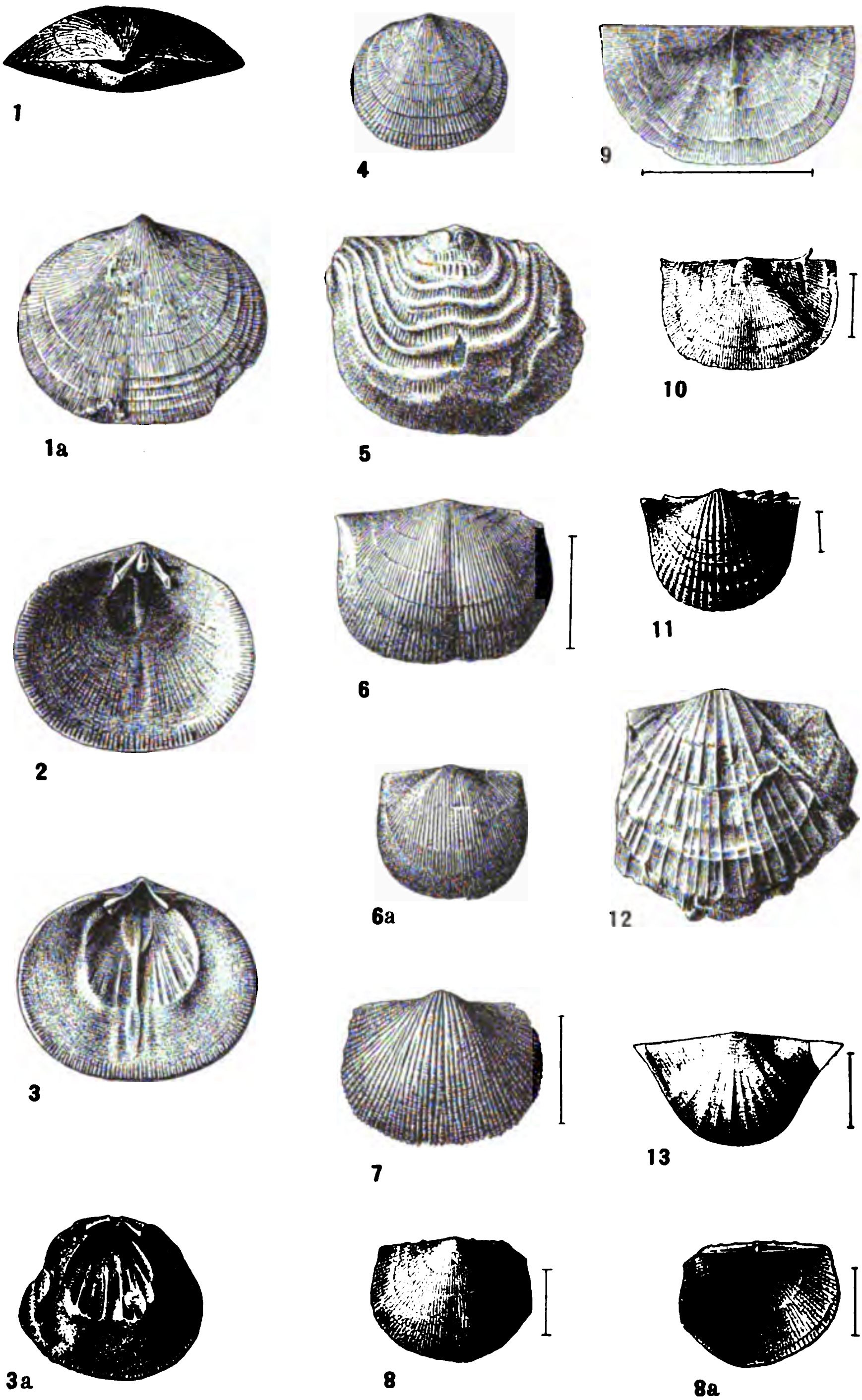
DEVONIAN LIMESTONES.

PLATE IV.



DEVONIAN LIMESTONES.

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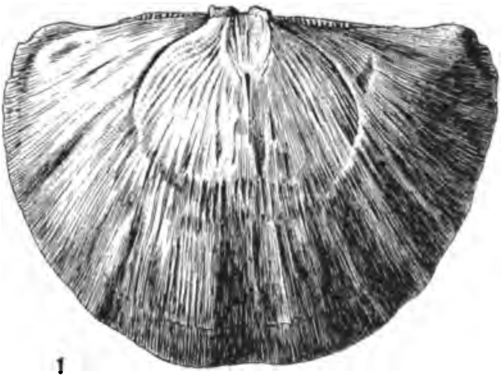

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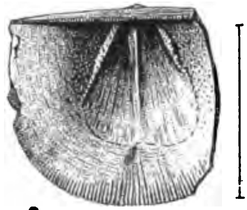

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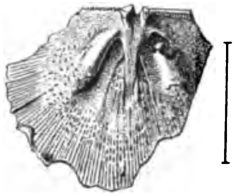

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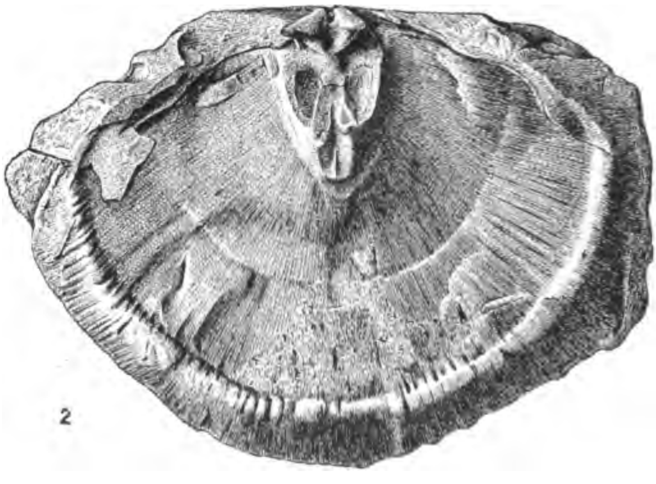

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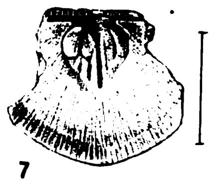

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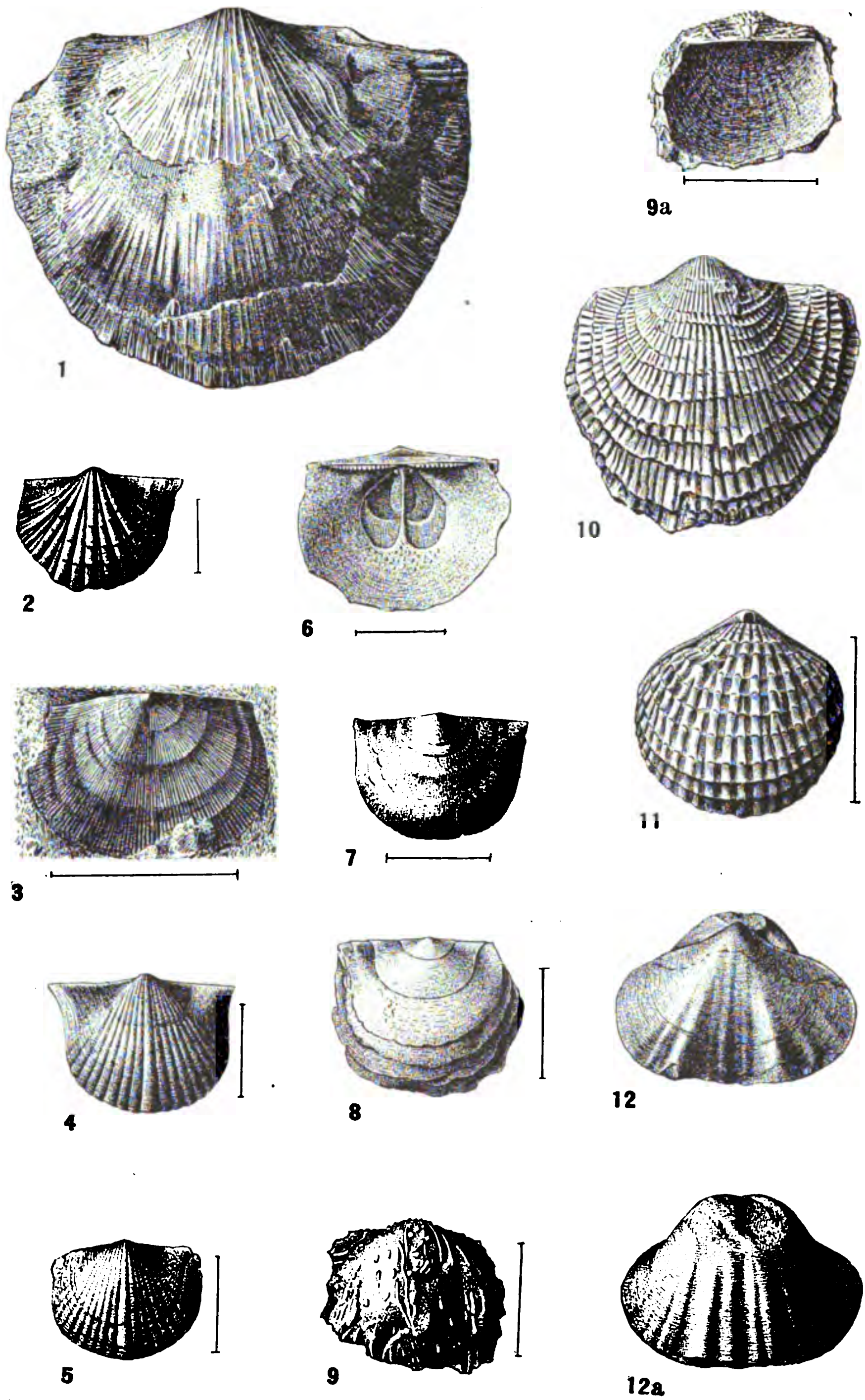

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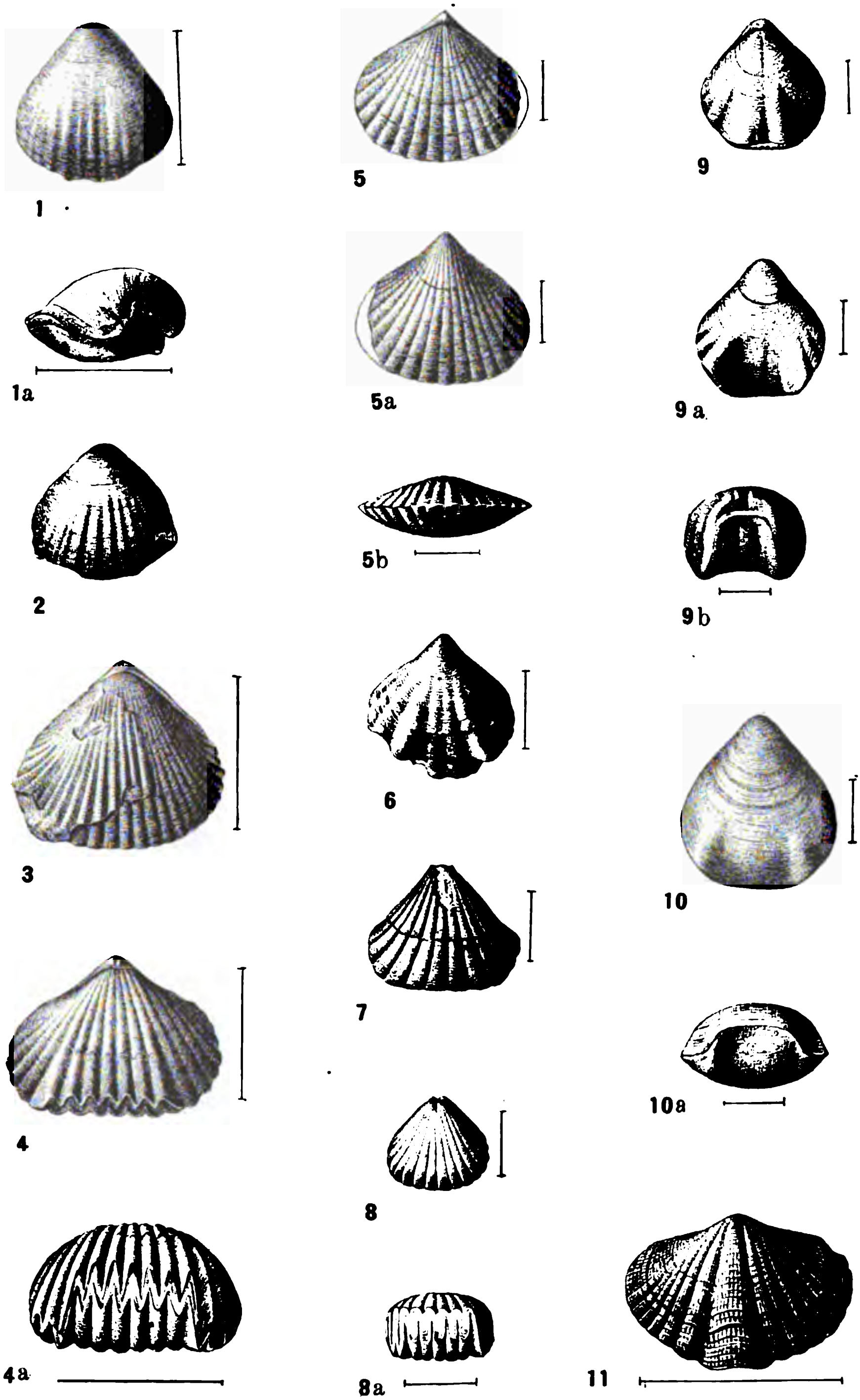

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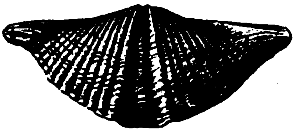
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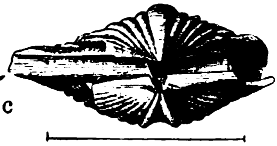
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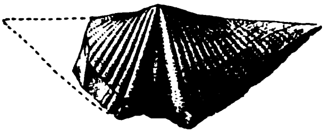
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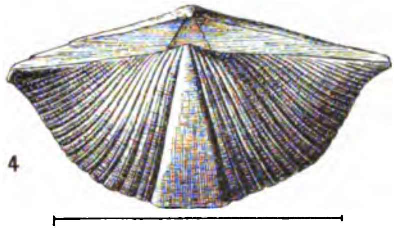
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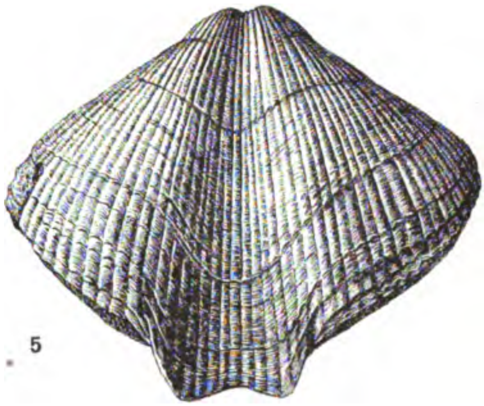
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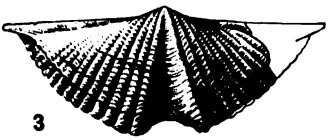
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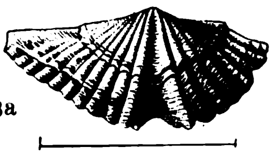
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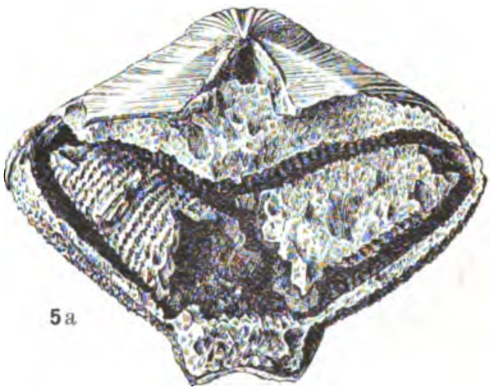
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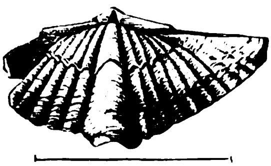
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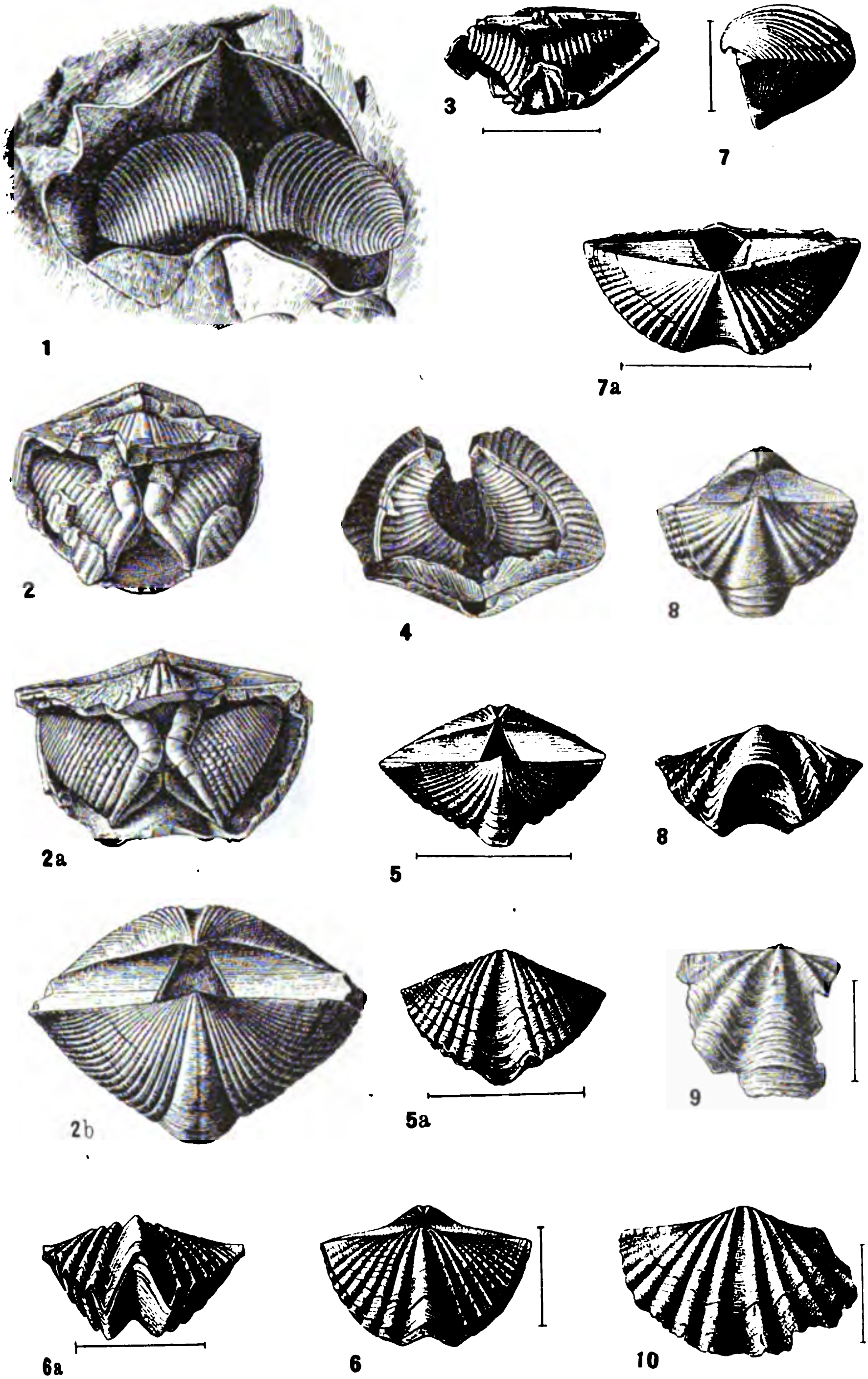

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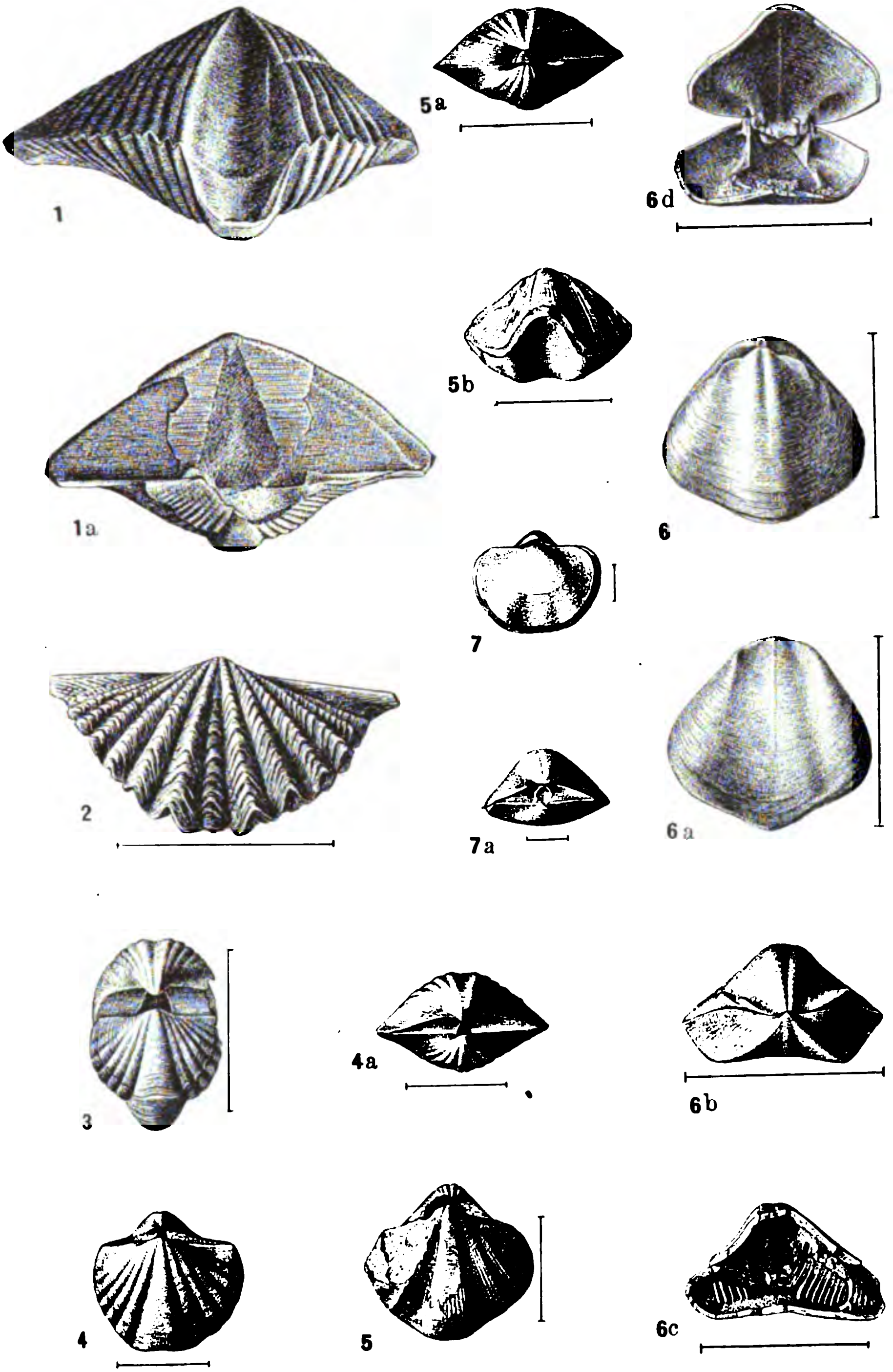

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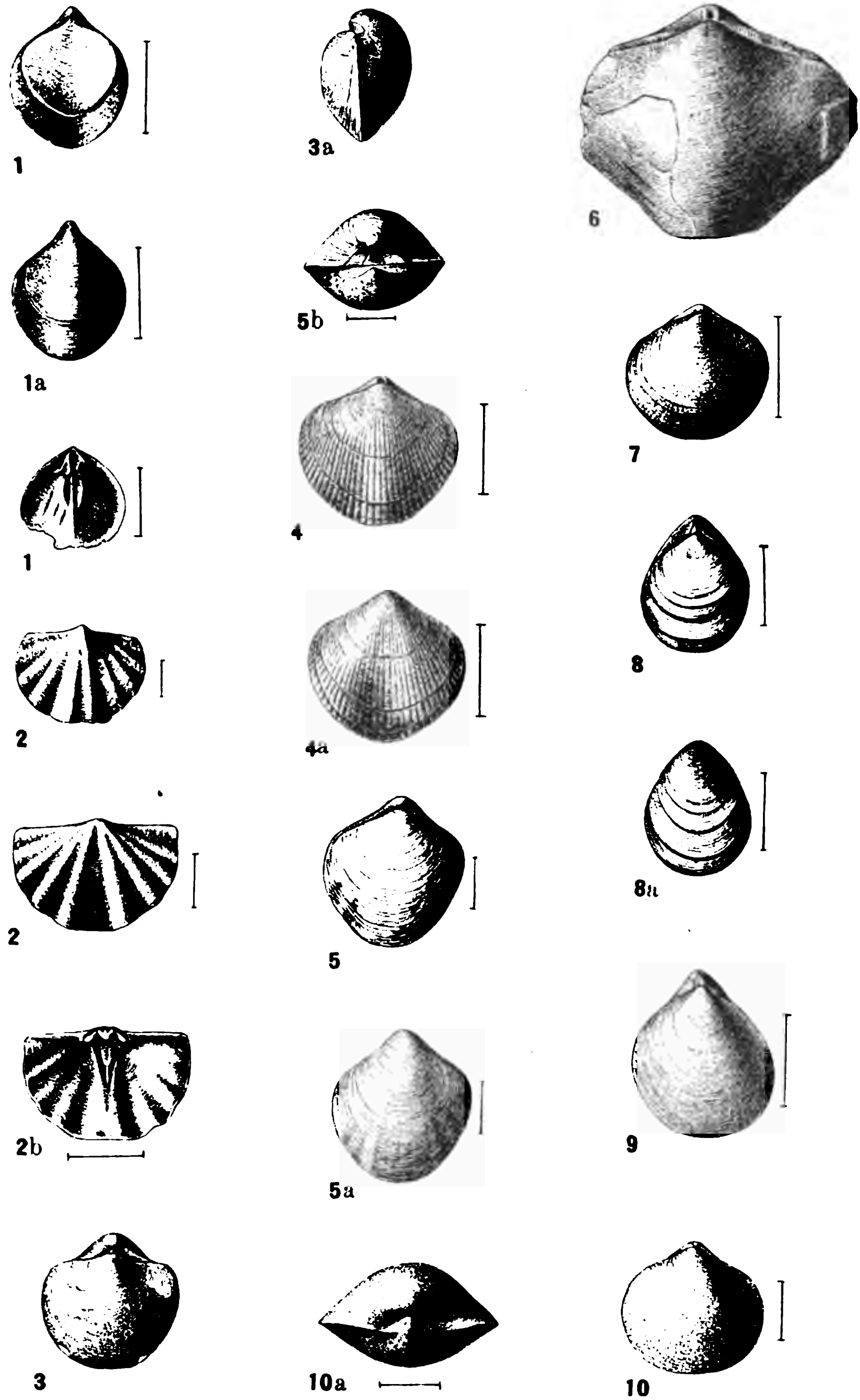

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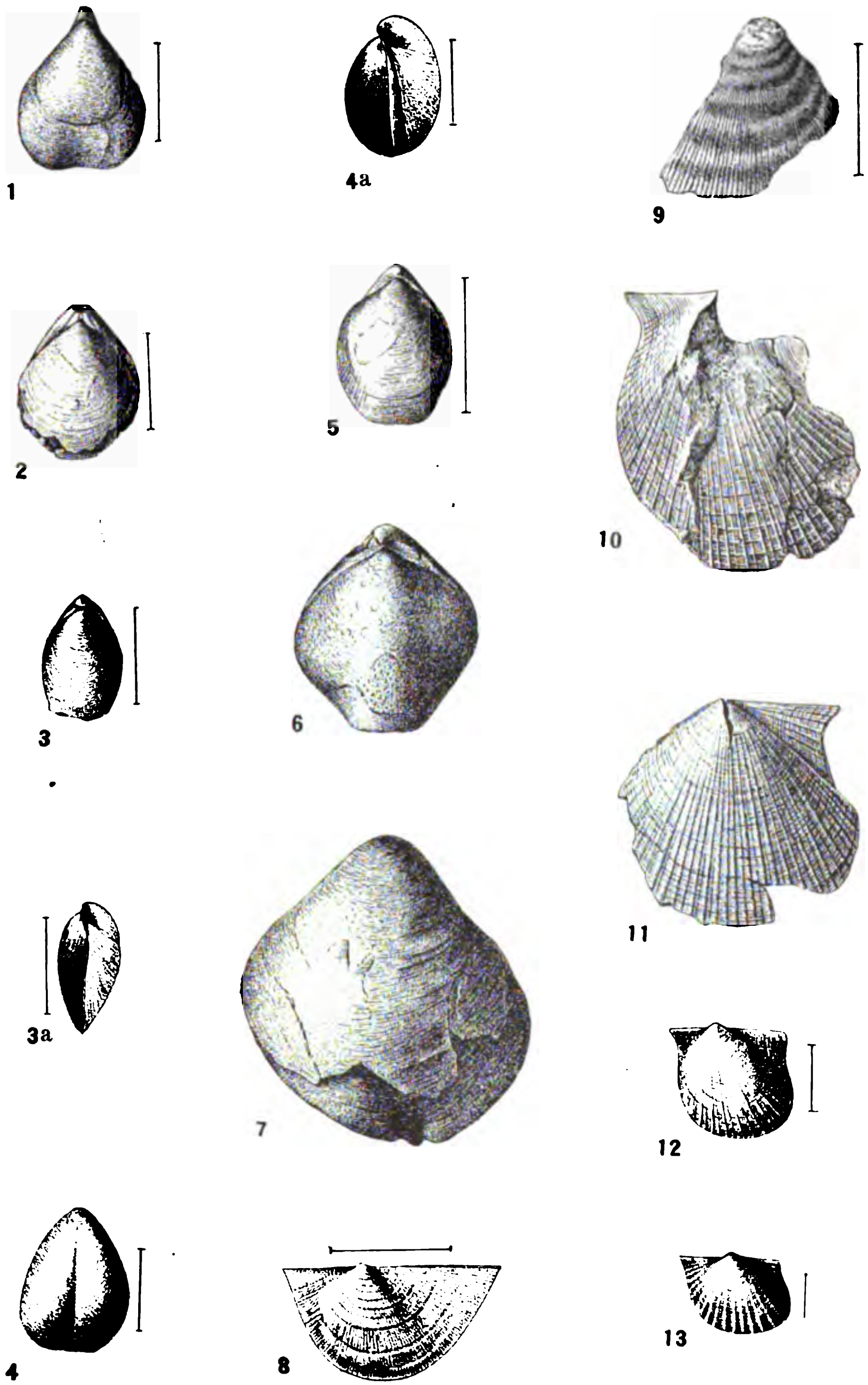

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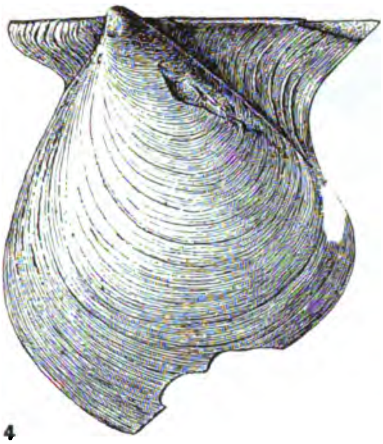

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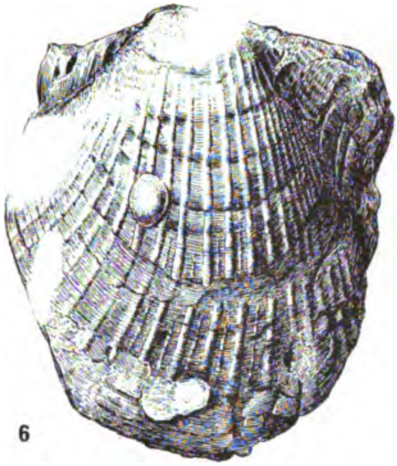

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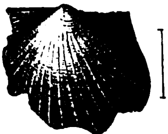

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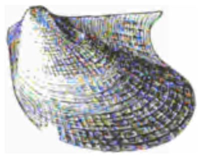

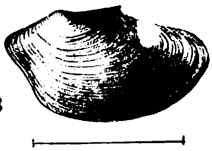

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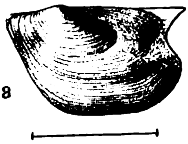

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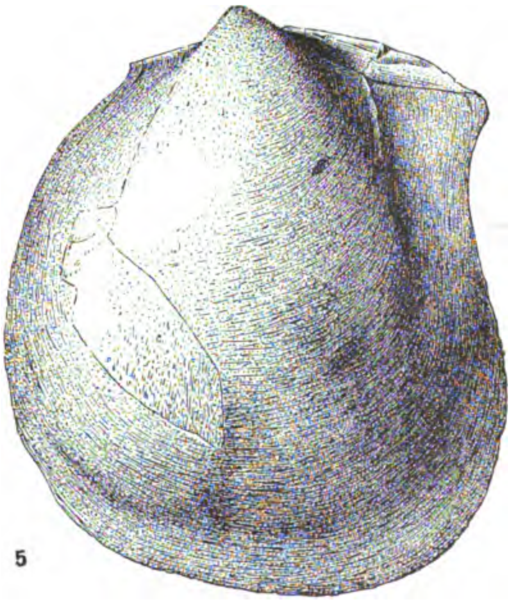

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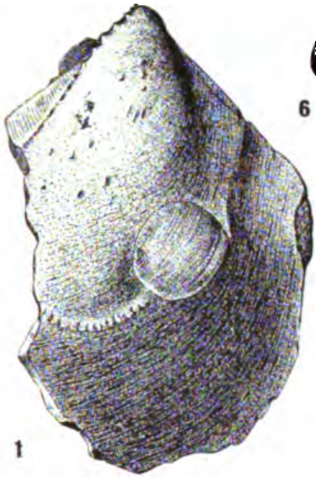
PLATE XIV.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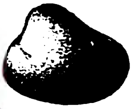
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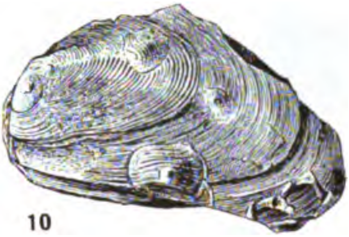
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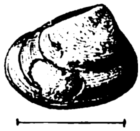
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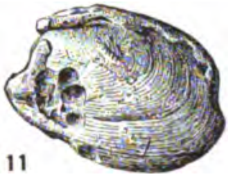
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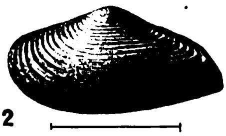
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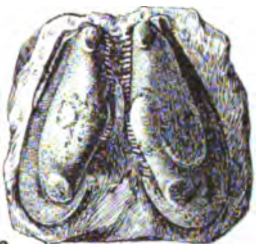
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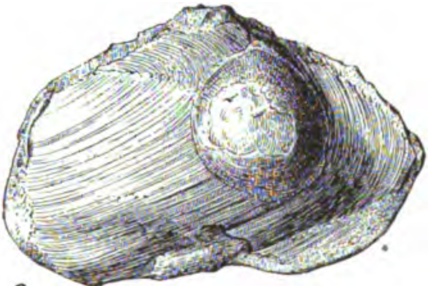
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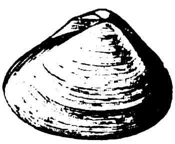
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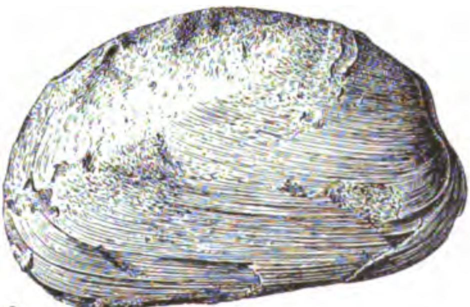
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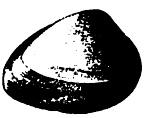
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PLATE XV.

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Fig. 1. *Paracyclas ohioensis* 675

Fig. 1a. Cardinal view of the same.

Fig. 1b. Left valve of another individual.
Sellersburg beds; Charlestown.

Fig. 2. *Ptychodesma knappianum* 671
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Fig. 2c. Interior of anterior end of left valve, showing hinge teeth.
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Jeffersonville limestone; Bunker Hill.

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Right valve.
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Right valve.
Jeffersonville limestone; Falls of the Ohio.

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Jeffersonville limestone; Falls of the Ohio.

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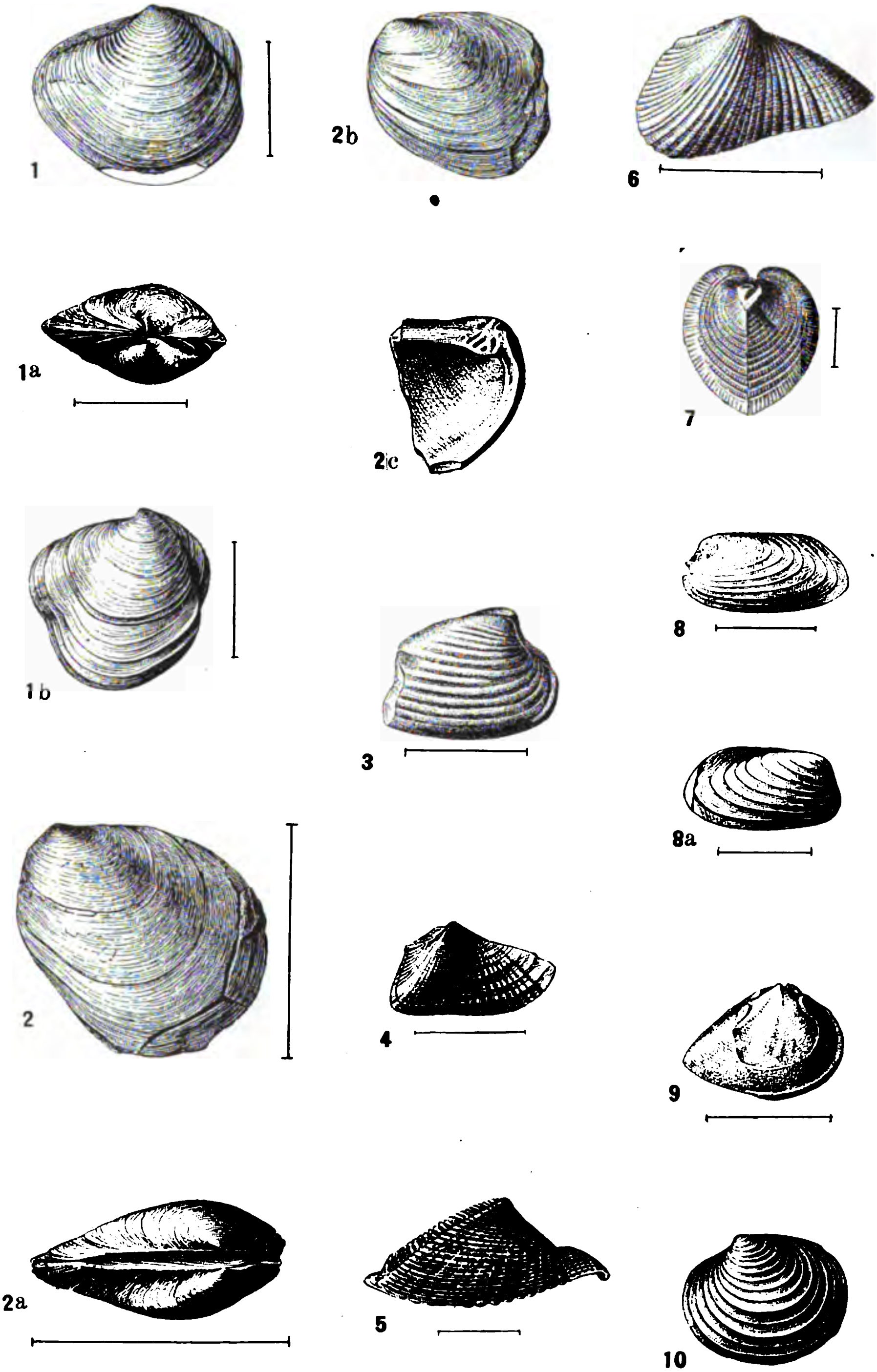
Natural cast of interior of right valve showing muscular scars.
Jeffersonville limestone; Newbern.

Fig. 10. *Paracyclas lirata*... 673
Left valve.
Sellersburg beds; Charlestown.



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	Natural cast of left valve showing muscular scar.	
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	Jeffersonville limestone; Falls of the Ohio.	
Fig. 9.	*Trochonema meekanum*	713
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Fig. 10.	*Naticopsis sp*	706
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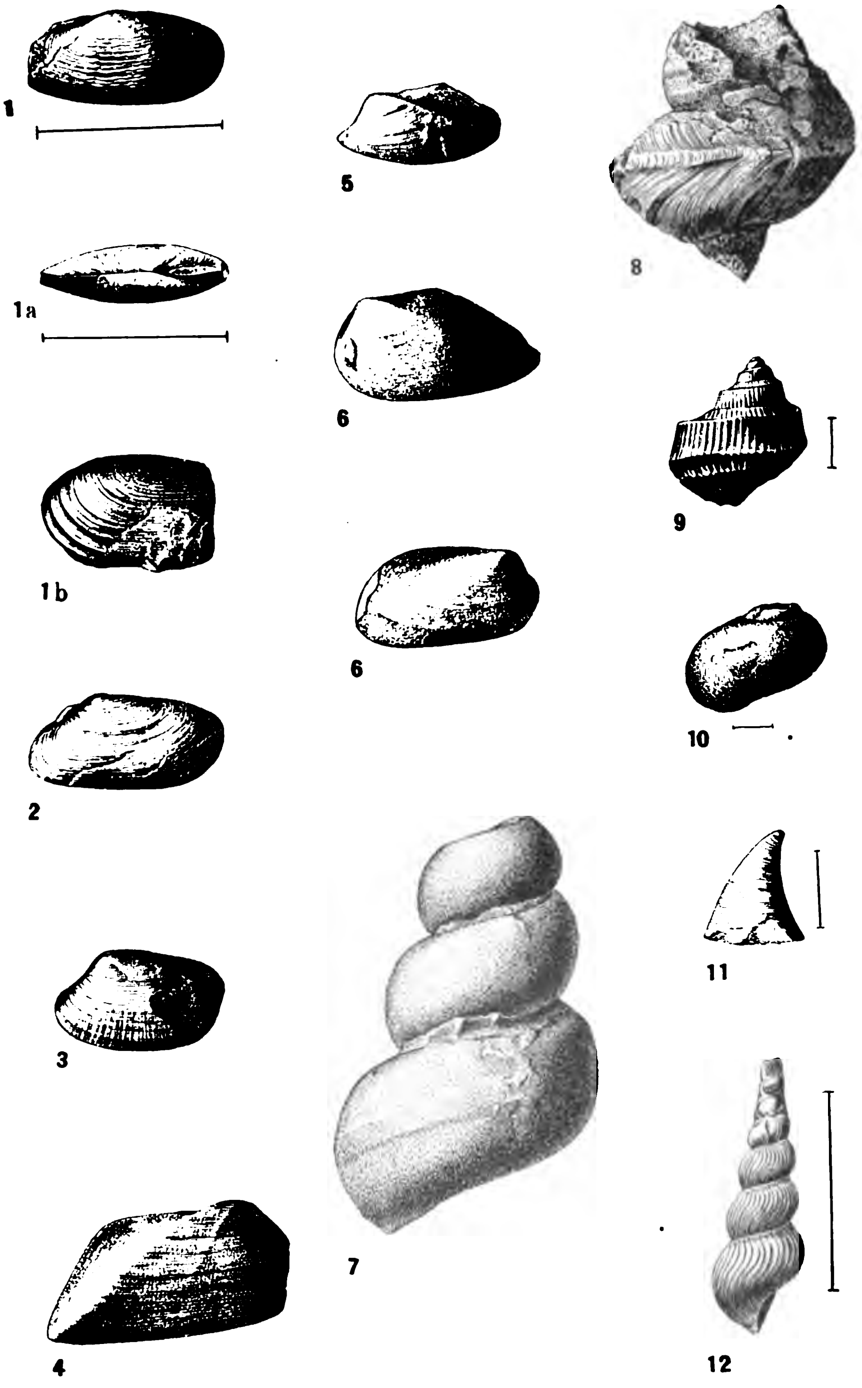

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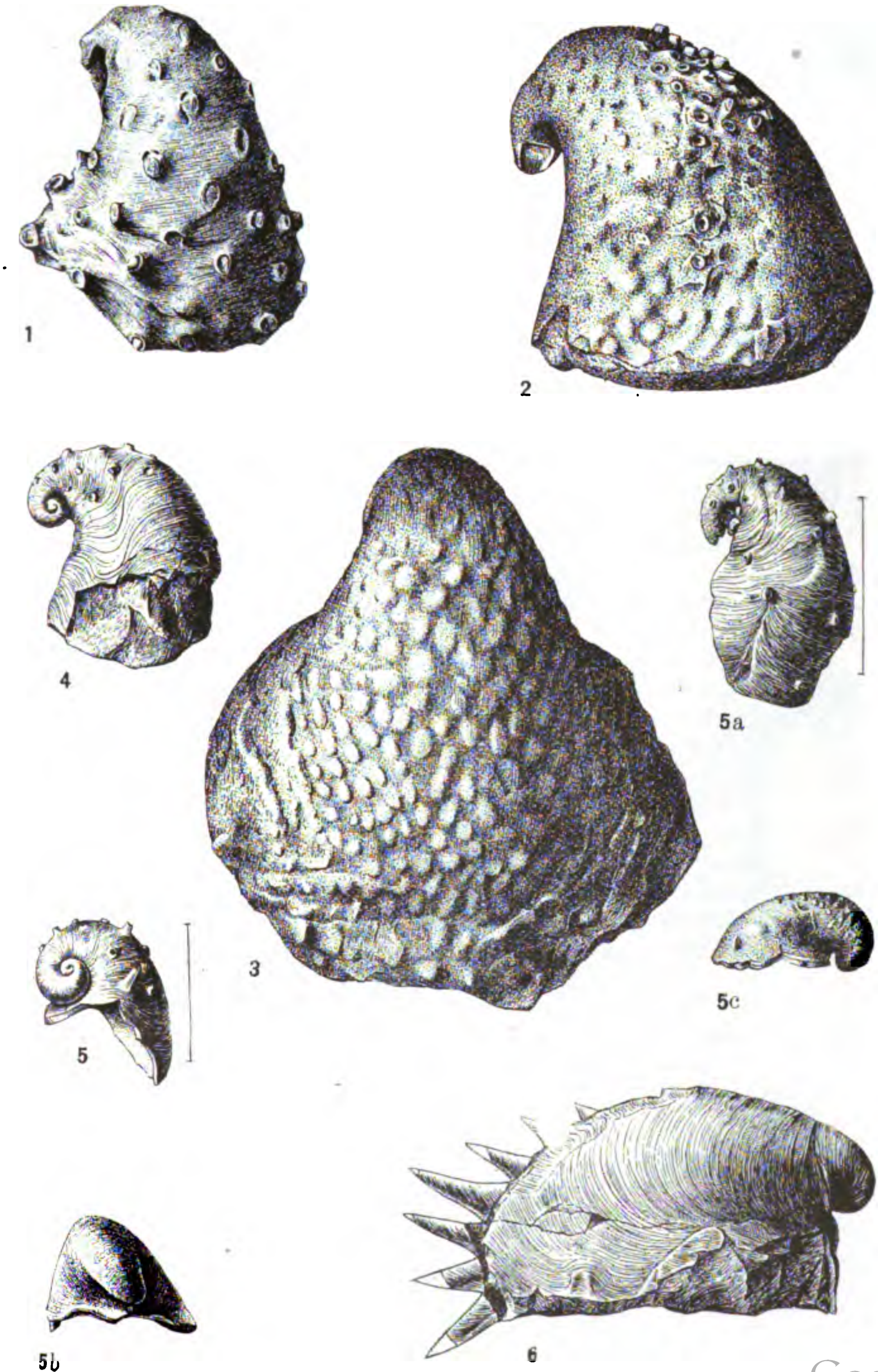
PLATE XVII.



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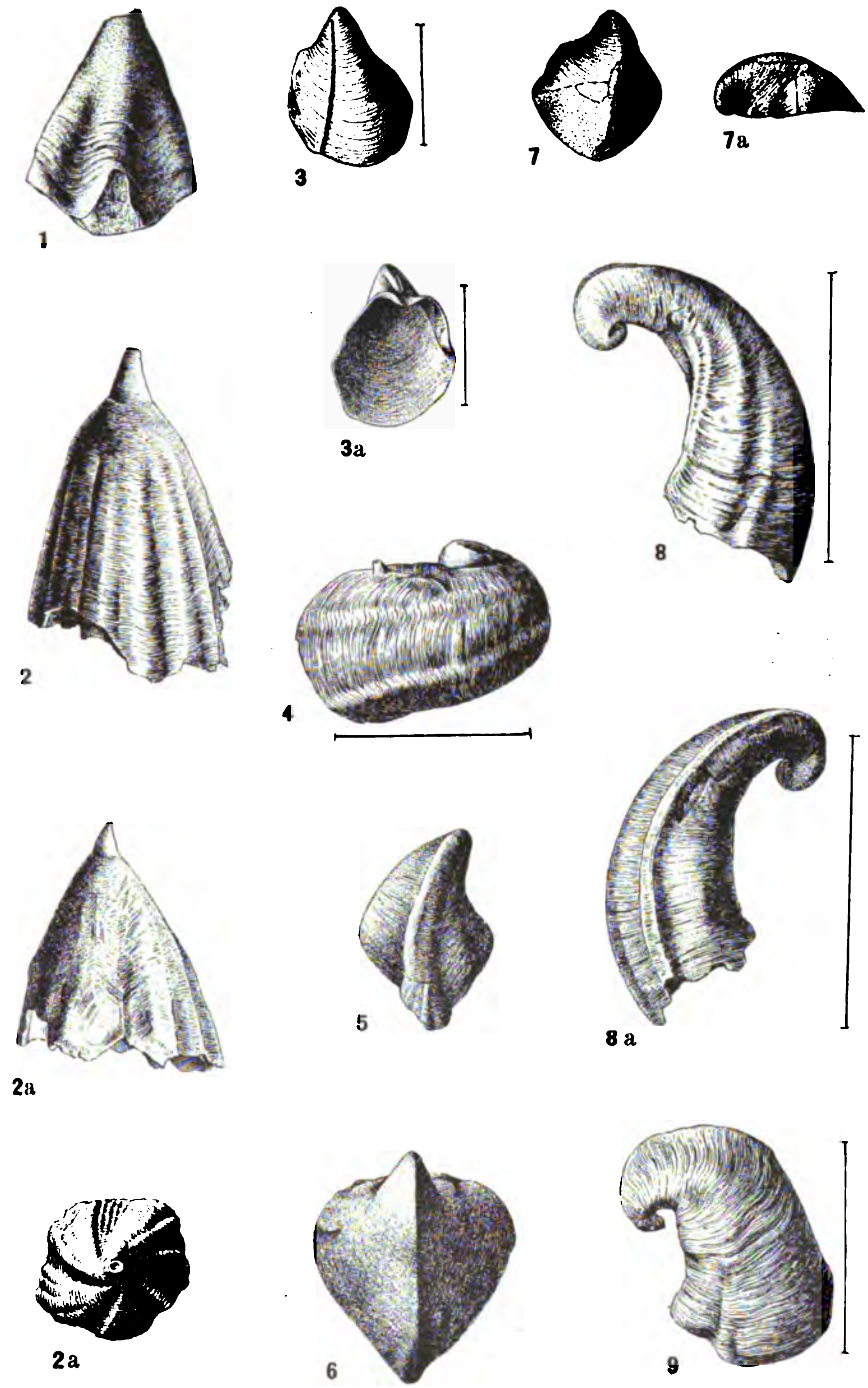

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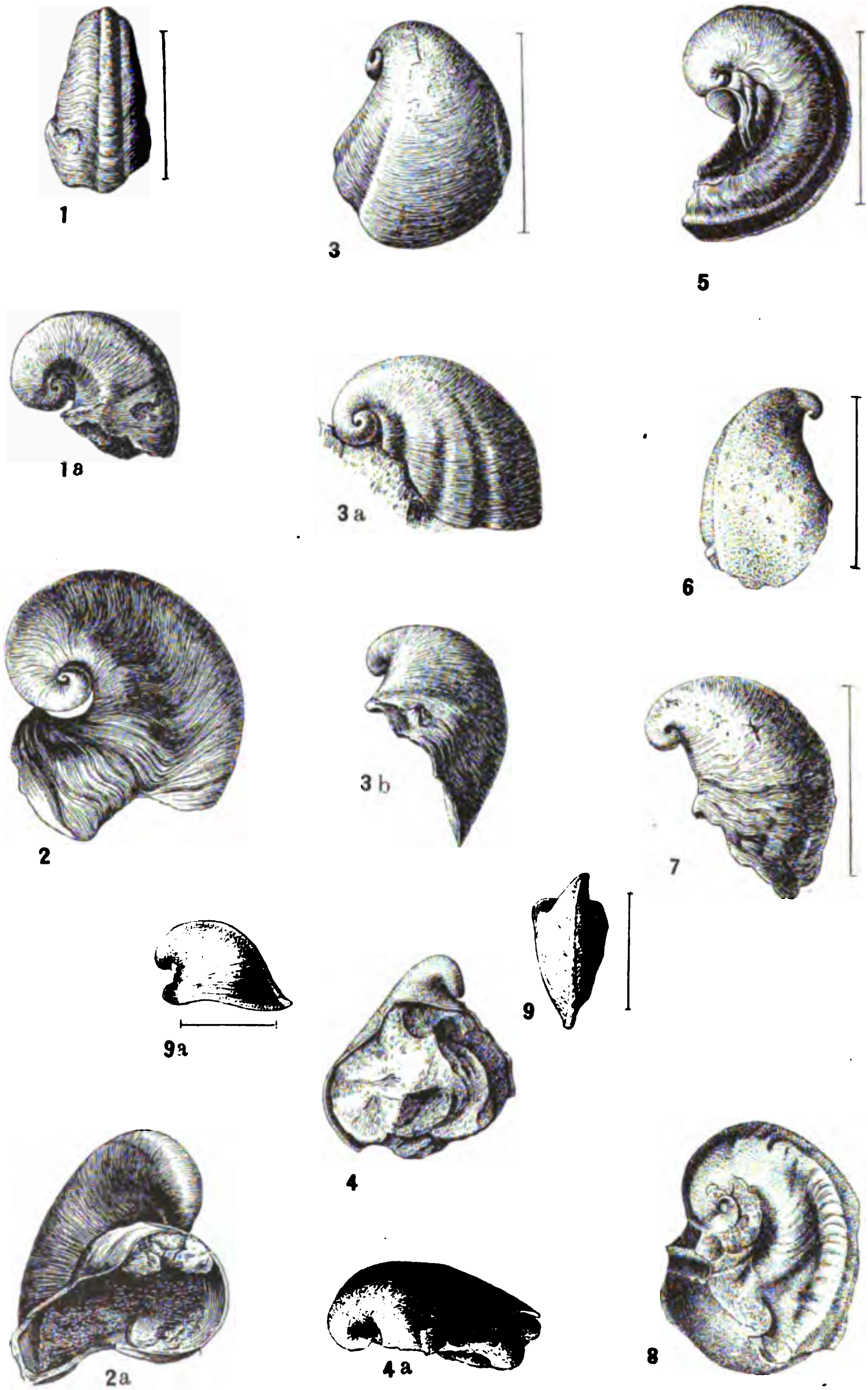
Jeffersonville limestone; Little Rock Creek, Cass County.



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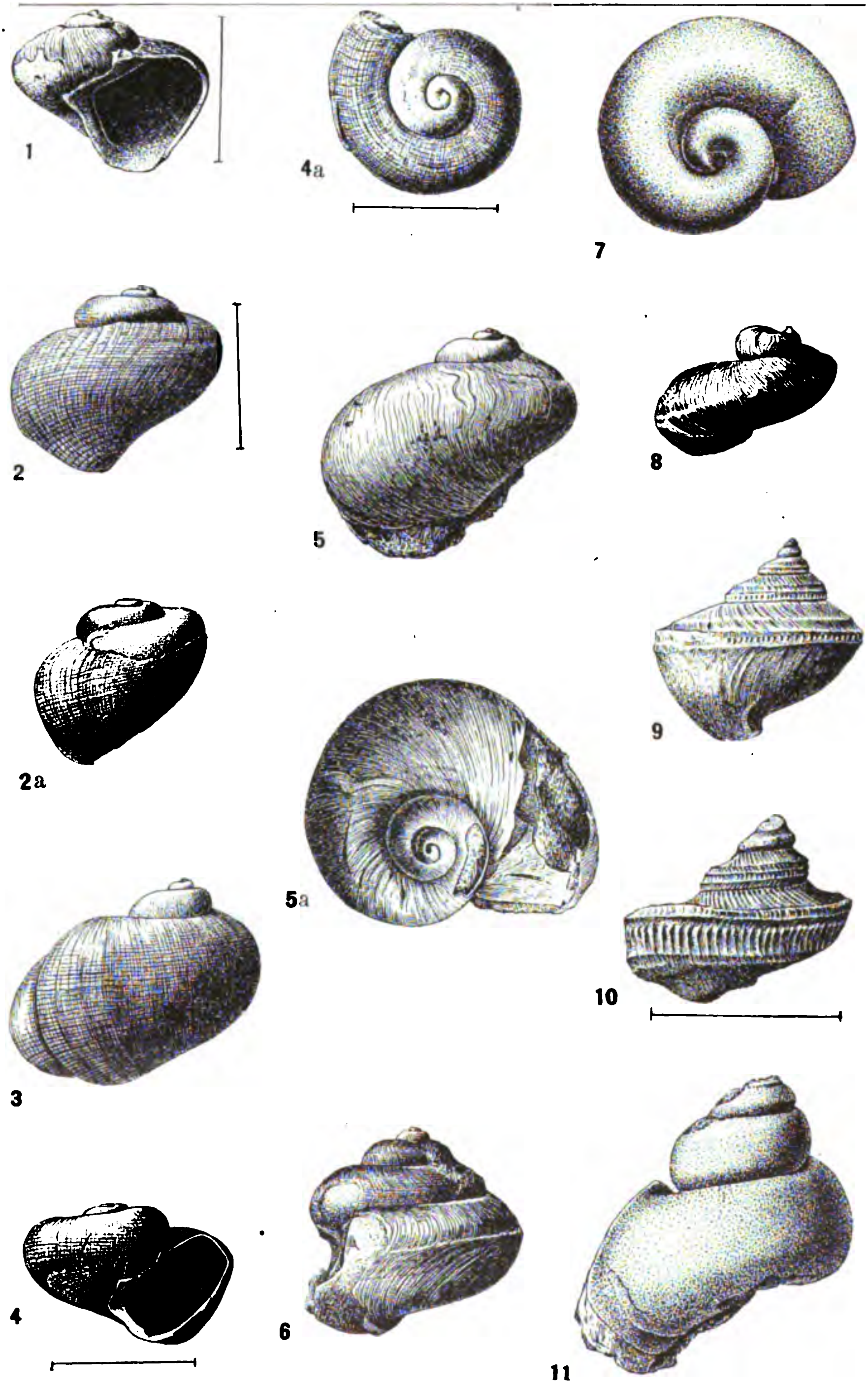

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PLATE XXI.

Pnge.

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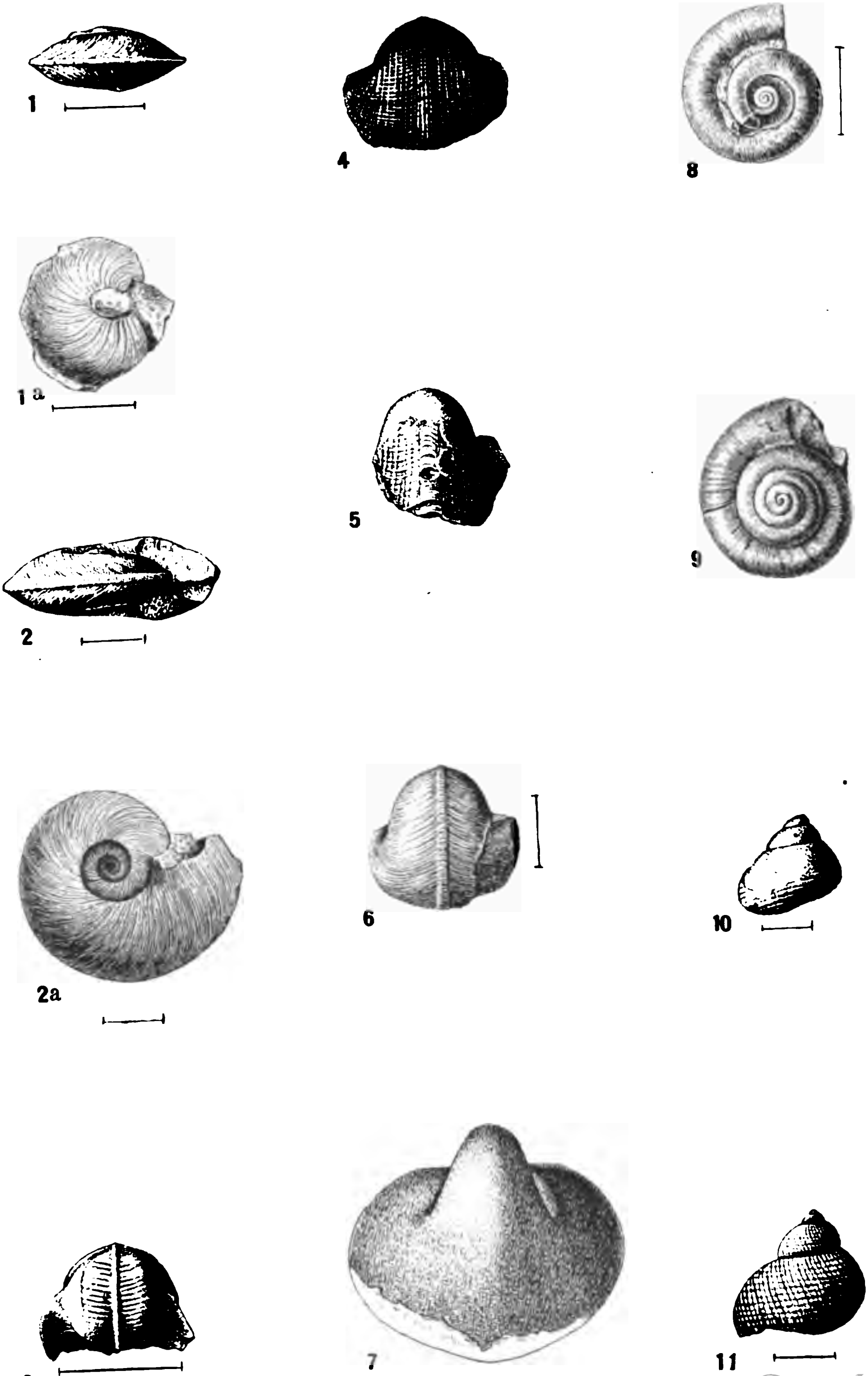

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PLATE XXII.

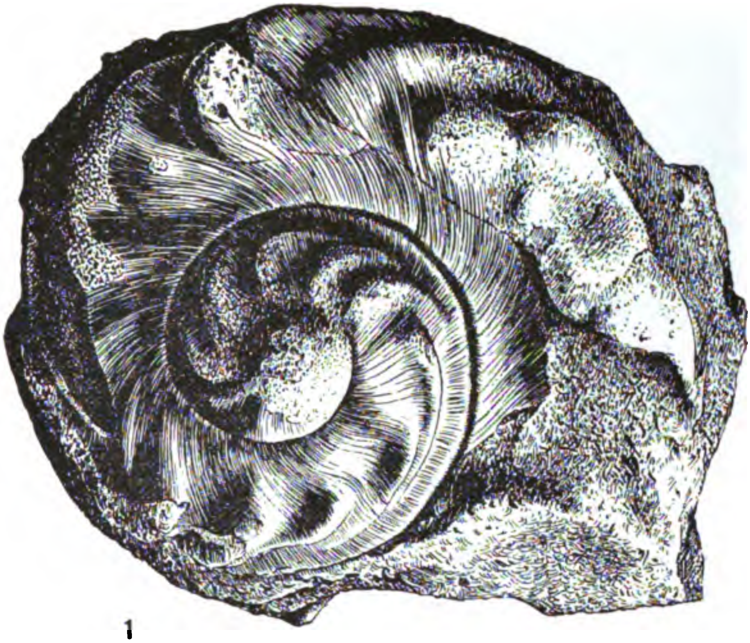

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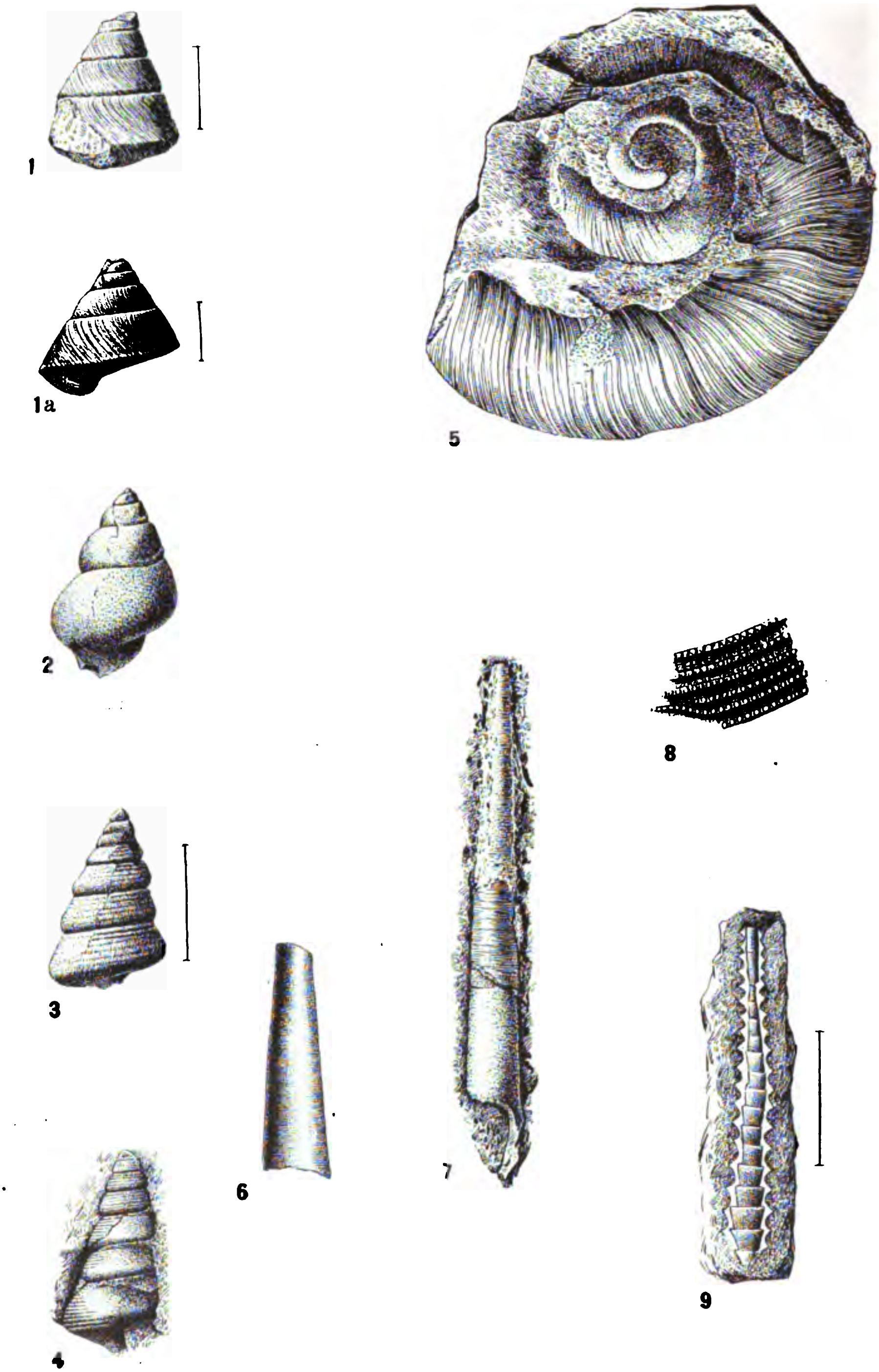
PLATE XXIII.



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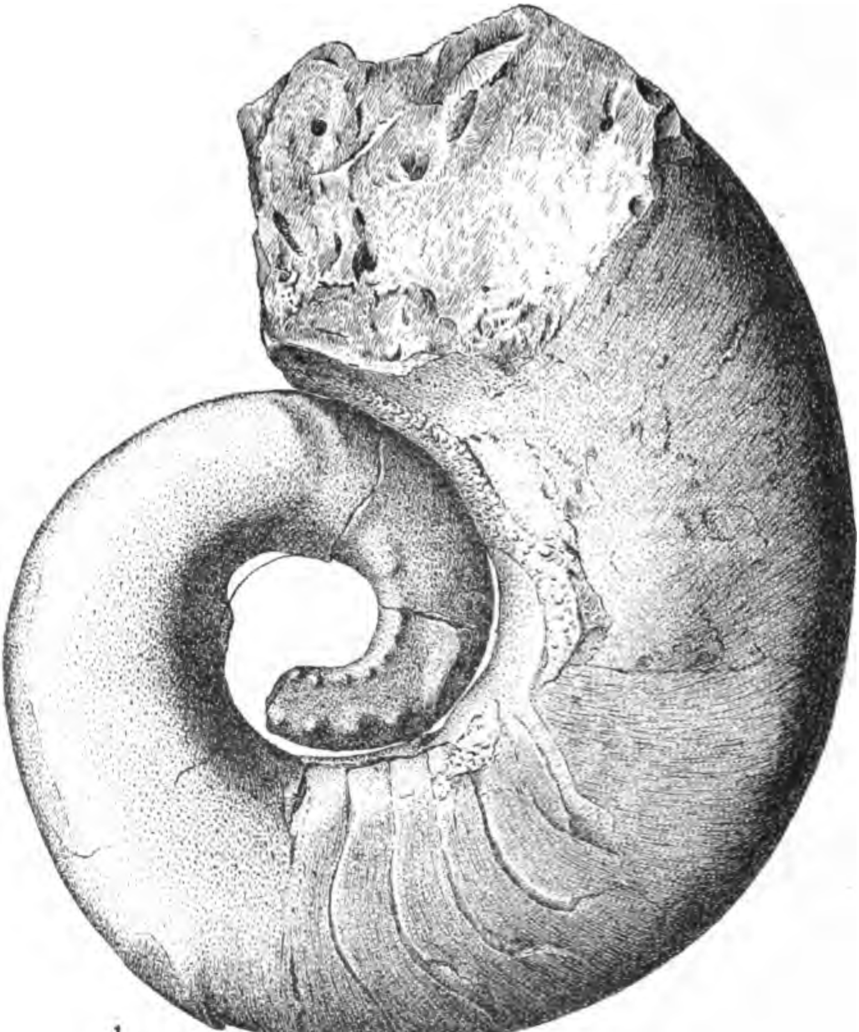

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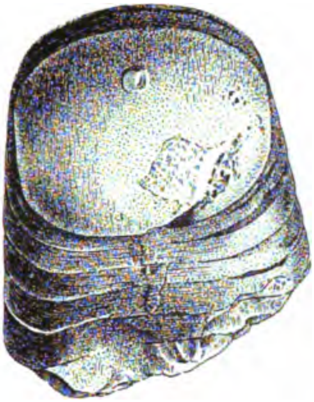

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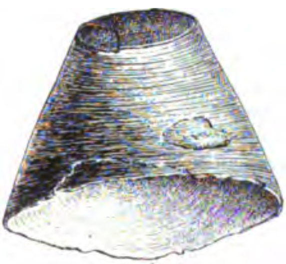

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PLATE XXVI.

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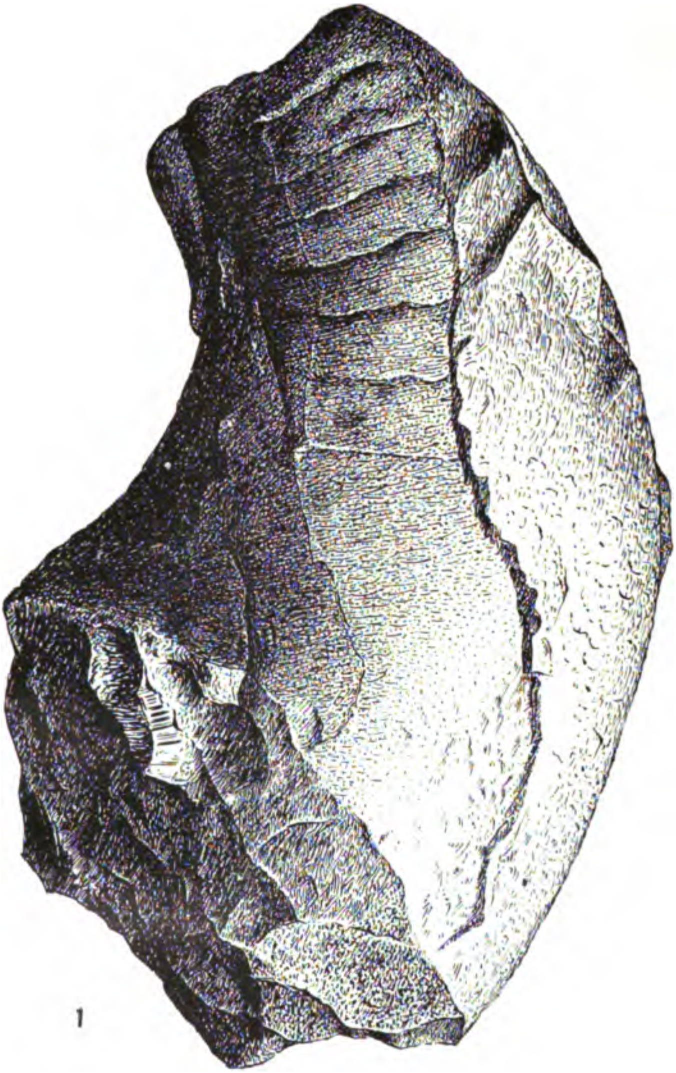
View of type specimen.

Jeffersonville limestone; Bunker Hill.



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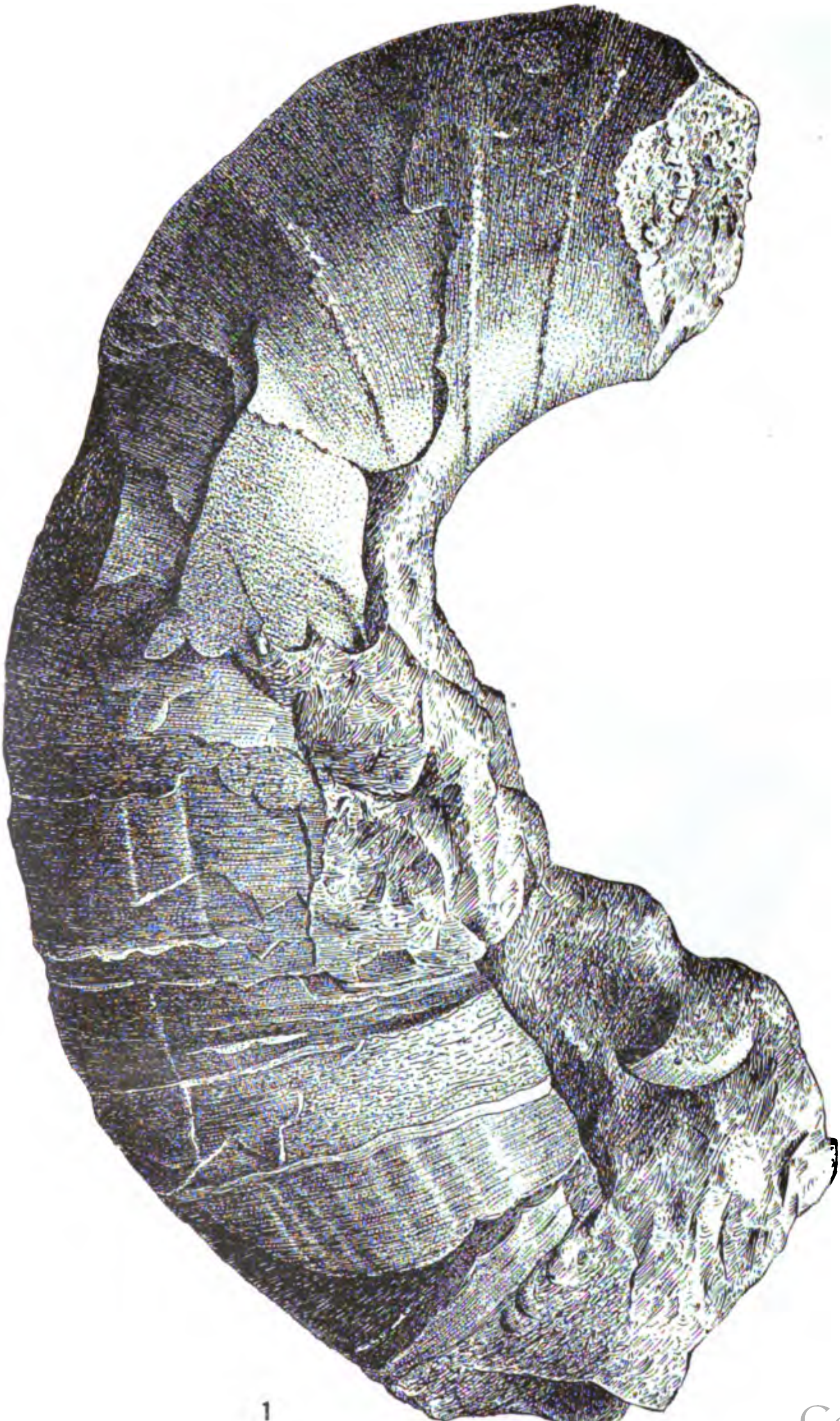
	Jeffersonville limestone; Lexington.	



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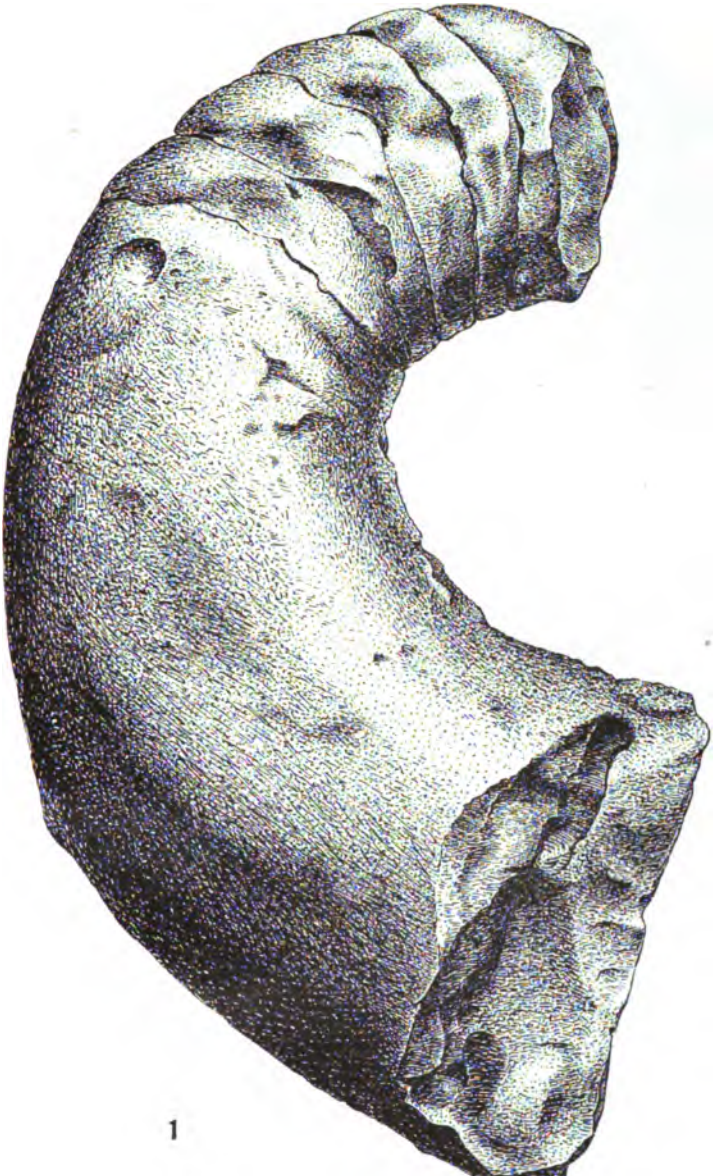

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PLATE XXIX.

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Fig. 1.	*Gomphoceras sp*	741

About seven-eighths natural size.
Jeffersonville limestone; Falls of the Ohio.

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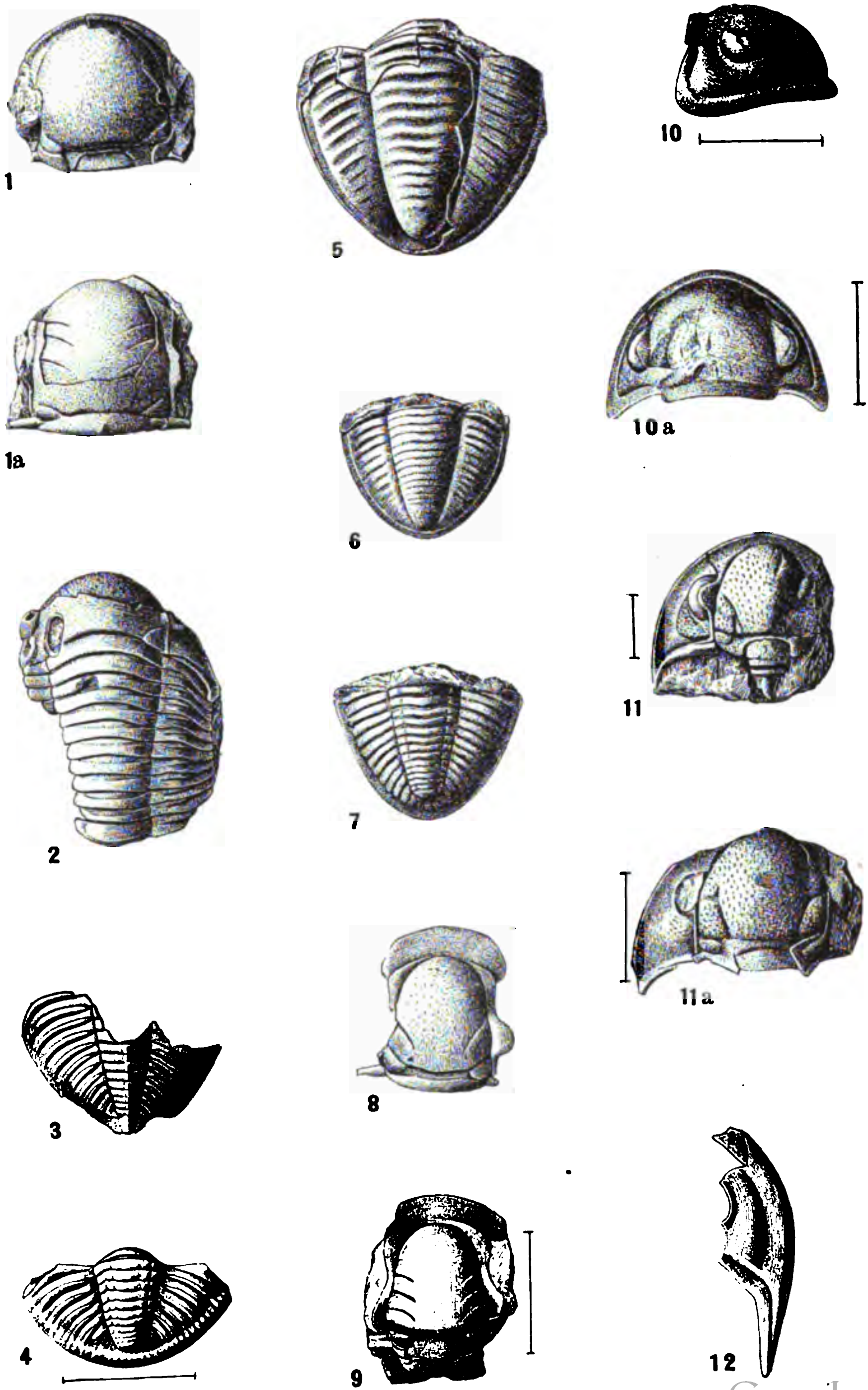

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View of an extended individual.

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Sellersburg beds; Charlestown.

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Pygidium.

Little Rock Creek, Cass County.

Fig. 4. *Dalmanites boothi* var. *calliteles* 754

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Jeffersonville limestone; Little Rock Creek, Cass County.

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Fig. 6. *Lichas sp* 758

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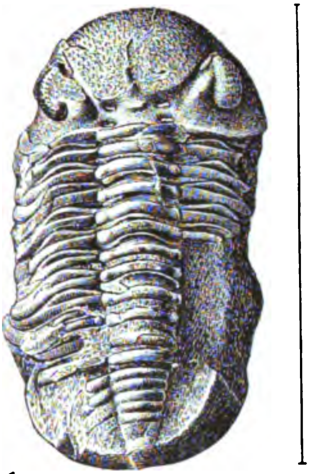
Jeffersonville limestone; Falls of the Ohio.



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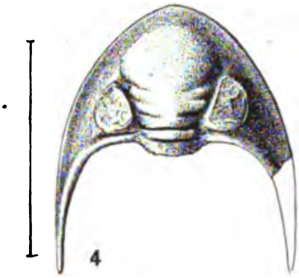

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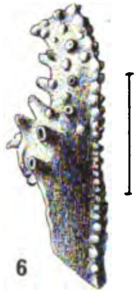

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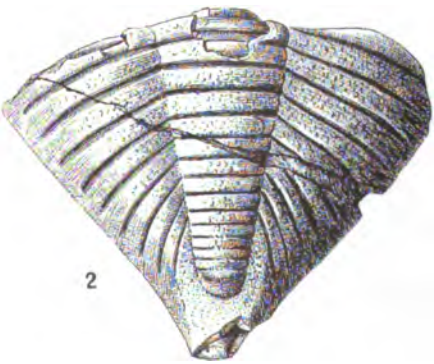

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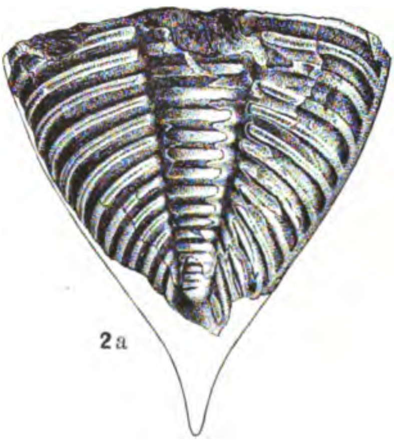

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